Three Papers on the Effects of Competition in Energy Markets

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

This thesis comprises three papers examining the impact of competitive pricing or competition on participants in energy markets. The scope of each paper is narrow but focused, dealing with one particular aspect of competition in each market under study. It is hoped that results from these three studies could provide valuable policy lessons to public policy makers in their task to create or maintain competition in different energy markets, so as to improve efficiencies in these markets.

The first and second papers examine the load shifting behavior of industrial customers in Ontario under real time pricing (RTP). Using Hourly Ontario Energy Price (HOEP) data from 2005 to 2008 and industry-level consumption data from all industrial customers directly connected to the transmission grid, the first paper adopts a Generalized Leontief specification to obtain elasticities of substitution estimates for various industry groups, while the second paper adopts a specification derived from standard consumer theory to obtain price elasticity estimates. The findings of both papers confirm that in some industries, industrial customers who are direct participants of the wholesale market tend to shift consumption from peak to off-peak periods in order to take advantage of lower off-peak prices. Furthermore, in the first paper, a demand model is estimated and there is evidence that the marginal effect of hourly load on hourly price during peak periods is larger than the marginal effect during off-peak periods. An important policy implication from the results of these papers is that while RTP is currently limited to industrial customers, it does have positive spillover effects on all consumers.

The third paper uses a unique panel dataset of all retail gasoline stations across five Canadian cities from late-2006 to mid-2007 to examine the effect of local competition on market shares and sales of individual stations. The base empirical specification includes explanatory variables representing the number of same brand stations and the number of different brand stations within a 3km radius to identify brand affiliation effect. It is found that the number of local competitors is negatively correlated with market share and sales. More interestingly, a same brand competitor has a larger marginal impact on market share and sales than a competitor of a different brand. These findings suggest that additional local competition leads to cannibalization of market share among existing stations, rather than create new demand. Another implication is that relying only on the number of different brands operating within a geographic market could understate the competition intensity in the local market.

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Chapter 1
Introduction

1.1 Motivation

This thesis comprises three papers on the impacts of competition on market participants in energy markets. The policy lessons drawn from these studies should help to inform policy makers in designing deregulatory reforms and competition policies that promote better pricing mechanisms in energy markets.

Pricing in energy markets has always been a major concern of public policy makers and the general public in Canada. It is commonly believed that energy use is essential to not only better standard of living, but also economic growth.[1] However, energy markets are often characterized by suppliers with monopoly power due to economies of scale in the production, transmission and distribution processes.[2] As a result, there is always pressure for government intervention to reduce or maintain energy prices, and to ensure an equitable and efficient allocation of resources.

Basing largely on economists' conviction that prices determined by a competitive market tend to lead to allocative efficiency,[3] governments has come to see introducing competition into a market or maintaining existing competition as a viable means to achieve these policy goals. In the electricity sector, for example, to ensure supply and affordability, most utilities have traditionally been provincial Crown corporations running as regulated monopolies, with generation, transmission and distribution functions vertically integrated and all rates regulated. However, very often political considerations could bring about systematic underpricing of electricity, resulting in inefficient use and

[1] Evidence that energy use positively impacts our standard of living can easily been seen around us: automobiles, air conditioners, refrigerators, microwave ovens, computers and many other modern day essentials all consume energy. As for evidence that energy use causes economic growth, it is much less clear. For example, in a recent survey of literature on energy consumption-economic growth and electricity consumption-economic growth causality nexus, Ozturk (2010) failed to find consensus on the existence of causality in the direction of energy (electricity) consumption to economic growth.

[2] See, for example, International Energy Agency (IEA) (2010) for a succinct description of the state of Canada's energy sector.

[3] This is a basic implication of the First Fundamental Theorem of Welfare Economics, also known as the "Invisible Hand Theorem".

lack of accumulated capital for capacity expansion.[4] In the past decade, the provinces have explored possibilities for market liberalization to various degrees. Alberta and Ontario have gone the farthest by adopting, among other measures, wholesale and retail competition[5] to improve the performance of their electricity industry.

Another example is the retail gasoline market. The fact that usually a majority of the retail outlets are owned by a few multinational and national oil companies, as well as prevalent phenomena such as seemingly coordinated price adjustments and asymmetric price cycles, has led many politicians and consumers to interpret observed movements and distribution of retail gasoline prices as results of collusive behaviors. It is therefore not unexpected that from time to time competition or antitrust authorities carry out inquiries to investigate possible infractions of competition or antitrust law.[6]

1.2 Summary of the Thesis

The three papers in this thesis each cover a specific aspect of competition in one of the two aforementioned energy markets in Canada. The first two papers focus on the demand response of industrial customers to real time pricing (RTP) in the recently created competitive wholesale electricity market in Ontario. The third paper focuses on the effect of local competition on market shares and sales of outlets in the retail gasoline markets in five cities across Canada. The following subsections briefly describe the context, the research problem, the method and the findings of each of the three papers.

1.2.1 Chapter 1 Summary

In Chapter 2 (Paper 1), I examine the load shifting behavior of industrial customers in Ontario under RTP. The wholesale electricity market in Ontario became competitive in May 2002 with the

[4] See, for example, Trebilcock and Hrab (2005) for the rationale of the electricity restructuring in Ontario.

[5] Ontario has adopted a hybrid model for its wholesale market, where the provincial government often offers contract guarantees and fixed prices to a majority of power generators and hence requires adjustments to the electricity prices set in the competitive wholesale market to account for such obligations (International Energy Agency (IEA), 2010).

[6] In Canada, the Competition Bureau has conducted numerous examinations of gasoline pricing over the years; most recently in 2005 following hurricane Katrina. Also, in 2004, the Government of Canada's Standing Committee on Industry, Science and Technology held hearings on the issue of price gouging by the oil industry. In all these inquiries, no evidence was found to substantiate the claims of conspiracy to fix retail gasoline prices.

introduction of real time pricing. All entities that are directly connected to Ontario's transmission grid, consisting of most power generation companies, large industrial customers and local distribution companies, must participate in the market. Simply put, in this real time market, generators submit offers for every five minute in each hour of the day, and then the Independent Electricity System Operator (IESO)[7] balances the supply and demand to reach a uniform, province-wide Market Clearing Price (MCP) for each five-minute interval. These interval prices are then averaged to determine the Hourly Ontario Energy Price (HOEP). To ensure the competitiveness of the market, the Ontario Energy Board's Market Surveillance Panel regularly monitors and reports on the behavior of the market and, with the help of the IESO's Market Assessment Unit, identifies and investigates any anti-competitive conduct by the market participants.

A properly implemented competitive real time pricing market should encourage the efficient use of electricity as customers would respond to higher prices by using less electricity and vice versa. This is particular important given the nature of electricity generation and consumption. Unlike most commodities, it is difficult to store electricity in large quantities for later use. There is also high cost of ramping up and down generation. Most electricity is therefore produced and then consumed immediately. Constrained by the capacity of the system, the marginal cost of electricity generation often rises sharply when the capacity is approached as the highest cost generators are dispatched to satisfy peak demands. Substantial benefits could therefore be reaped if demand can be reduced through load shifting by the customers away from peak demand periods. In considering demand response programs that induce such load shifting behavior from customers, of which real time pricing can be considered as a form of "price based" demand response, Rowlands (2008) describes potential economic benefits, in terms of lower prices and deferred investment requirements for additional system capacity, which accrue not only to the customers who load shift but also to all customers. There are other potential benefits to society in terms of improved reliability of the electricity grid, reduced environmental impact and increased economic development as a result of lower electricity prices.

The success of "price based" demand response depends on the extent to which customers is willing to reduce use of electricity and/or to substitute peak hours use with off peak hours use. In this paper,

[7] In pursuant of the Electricity Act, 1998, and as a result of the breakup of Ontario Hydro on April 1, 1999, the IESO is charged with the responsible of administering the electricity markets and the operation of the transmission grid in Ontario.

to estimate this responsiveness, I estimate the direct elasticity of substitution between peak hours electricity and off peak hours electricity. It measures the percentage change in the ratio of peak hours use to off-peak hours use as the ratio of peak hours price to off peak hour price changes. I use Hourly Ontario Energy Price (HOEP) data from 2005 to 2008 and industry-level consumption data from all industrial customers directly connected to the transmission grid to obtain elasticity of substitution estimates from a General Leontief (GL) cost model for different industrial sectors. In addition, to assess the claim that demand response can lead to lower prices for all customers, not just load shifting customers, I estimate a province specific demand model separately for peak hours periods and off peak hours periods to examine the effects of load shifting on hourly prices.

Nonlinear Seemingly Unrelated Regression (SUR) estimates of the elasticities of substitution from the GL cost model confirm that in some industries, industrial customers who are direct participants of the wholesale market tend to shift consumption from peak to off-peak periods in order to take advantage of lower off-peak prices. Furthermore, the Generalized Least Squares (GLS) estimates from the province specific demand model shows that the marginal effect of hourly load on hourly price during peak periods is larger than the marginal effect during off-peak periods. The policy lesson is that market based schemes that encourage RTP should result in positive spillover effects on all consumers.

This paper differentiates itself from previous studies by the inclusion of all industrial customers who are directly connected to the transmission grid and hence are required to be participants in the wholesale market in its estimation of the elasticities of substitution. As previous studies usually include a subset of voluntary participants of a particular demand response program, their elasticities of substitution would tend to be biased upward as self-selection would imply that customers who are more able to load shift would be more likely to participate. The smaller estimates in this paper, as compared to those in previous studies, may indicate the absence of such self-selection bias and therefore can be better extrapolated to assess the effect of extending RTP to other components of electricity pricing (transmission charge, for example) on load shifting.

1.2.2 Chapter 3 Summary

In Chapter 3 (Paper 2), I continue the investigation of the demand response of industrial customers to RTP in Ontario's whole electricity market. Instead of the production cost approach adopted in Chapter 2, I obtain estimates of price elasticities for different industrial sectors from model specifications derived from standard consumer theory. In particular, I estimate the own price elasticities and cross price elasticities, where peak hours electricity and off peak hours electricity are considered substitutes in the models. Using the same data set as in Chapter 2, GLS and Instrumental Variables (IV) estimates are contained which show that some industrial customers do reduce demand in response to price (i.e. negative own price elasticities) and substitute peak hours electricity with off peak hours electricity (i.e. positive cross price elasticities).

One rare feature of the analysis in this paper is the use of instrumental variable estimation. Instrumental variables are not commonly used in previous studies, many of which are based on nonlinear flexible functional form. The simpler model specifications in this paper allow the use of an instrumental variable, namely the difference in temperatures between Toronto and New York City, to adjust for possible reverse causation and omitted variable biases. In general, the IV results support the findings from GLS estimation in this paper and also the findings from more complex nonlinear specifications in Chapter 2. This demonstrates the robustness of the conclusion that industrial customers in some industries do reduce consumption in response to higher prices and shift consumption from peak periods to off peak periods.

1.2.3 Chapter 4 Summary

In Chapter 4 (Paper 3), I examine the effect of the number of local retail gas outlets on station specific market shares and sales. There are many competitors in the retail gasoline sector in Canada. In additional to stations affiliated with multinational vertically integrated firms such as Shell and Esso, the national firm, Petro Canada, and regional vertically integrated firms such as Ultramar, Irving, Sunoco[8], Chevron, Arco, Husk, Federated Co-op and Parkland, there are many big box store outlets, such as Canadian Tire, Real Canadian Superstore, Save-on Foods and Costco, and a large number of small independent outlets. While there is research on the effects of local sellers on retail gasoline prices, the effects of competition on station specific market shares and sales have usually been ignored. The differences between within brand and between brand competition as well as the relative impacts of vertically integrated refiners and independents have not been extensively studied. Empirical evidence generated by this paper should be useful to fill these gaps.

[8] Suncor Energy Inc., the parent company of Sunoco-branded retail outlets, acquired Petro-Canada in 2009. Sunoco-branded outlets were converted to Petro-Canada outlets or were sold to Husky Energy Inc and then operated under the Husky brand.

I exploit a panel dataset of retail gasoline stations across five Canadian cities from late-2006 to mid-2007 to explore the effects of local competition on station specific market shares and sales. These data consist of the universe of outlets in each city. Unique to many of the similar studies on local competition of retail gasoline outlets, in this paper, the base empirical specification includes explanatory variables representing the number of same brand stations and the number different brand stations with a 3km radius to identify brand affiliation effect. Unsurprisingly, it is found that higher number of local competitors is correlated with lower station-specific market share and sales. More interestingly, it is also found that competing outlets belonging to the same brand possessing a slightly larger marginal impact. These findings are robust to the use of covariates controlling for station specific characteristics as well as firm fixed effects. In tandem, these estimates suggest that (1) more outlets may actually result in lowered surplus through cannibalization of existing market shares; and (2) relying on the total number of outlets of different brands within a geographic market may be a misleading benchmark of competition intensity.

1.2.4 Common Themes

Individually, the three papers share two common research goals: (1) to provide policy relevant empirical evidence based on market conditions in Canada and, and (2) to make unique contributions to the existing literature. With respect to the first goal, all three papers focus on a narrowly but clearly defined reform measure or aspect of competition in the respective markets being studied and provide empirical estimates of the impacts of competition on market participants. With respect to the second goal, the first paper differs from existing studies on RTP in two ways. First, while most studies of RTP in other jurisdictions utilize firm-level data from a subsample of customers facing RTP, this study utilizes industry-level data including all customers facing RTP. As far as estimating average industry response is concerned, our data set should minimize any bias from non-random selection of study, which would be a concern in other studies. Second, there are few econometric studies of the effects of load shifting on prices, most studies use simulation methods which do not take into consideration secondary effects. The second paper distinguishes itself from other similar studies with the use of instrumental variables to account for possible reverse causation and omitted variables. As for the third paper, the focus on brand affiliation effect in this context is rare in the literature. While there are a few studies of the effects of brand affiliation on station prices, there seems to be few similar studies on station market shares.

Taken together, the three papers complement each other by presenting a series of investigations that cover a broad spectrum of market and participant types, and trends and policy focuses. The first two papers are concerned with a wholesale market from the buyers' perspective, while the third paper is concerned with a retail market from the seller's perspective. The electricity sector studied in the first two papers is in transition from highly regulated to a competitive market model with less control, and the policy focus is on improving efficiency through the introduction of market-based prices. In contrast, the retail gasoline market studied in the third paper is much less regulated, and the policy focus is to ensure competition through more regulations or intervention to curb anti-competitive behavior by firms if necessary.

In addition to the three papers in Chapters 2 to 4, this thesis concludes with Chapter 5, which synthesizes the results from the three papers, mentions limitations of the studies and suggests avenues for future research.

Chapter 2

Response of Industrial Customers to Hourly Pricing in Ontario's Deregulated Electricity Market[9]

2.1 Introduction

How do industrials moderate their electricity consumption in response to wholesale prices? And does their behavior impact system wide electricity prices? The answers to these questions have considerable policy implications, as they reveal the efficacy of demand response (DR) programs focused on industrials.[10] The past decade has witnessed the implementation of Real Time Pricing (RTP) schemes through the introduction of competitive wholesale markets in North America. The benefit of such pricing is that consumers are directly exposed to prices that change on an hourly basis and can adjust their consumption accordingly. Large industrials that are directly connected to the transmission grid may be able to reap considerable benefits by responding dynamically and in real time to changes in wholesale electricity prices, such as in peak hours. Further, as noted by Borenstein, Bushnell, and Wolak (2002), RTP participants have the option of choosing hedge options in order to reduce price volatility.

However, load shifting by industrials – the biggest consumers of electricity in Ontario – from peak to off-peak hours could theoretically benefit all consumers through a reduction in wholesale electricity prices. A significant amount of research suggests that the supply curve for electricity in Ontario and for many other jurisdictions to be J-shaped. In other words, the supply curve is relatively elastic, with curvature determined by the marginal cost of supply generation. Incremental changes to prices from higher demand will not be large until capacity constraints are approached and the supply

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[9] This chapter is coauthored with Anindya Sen and Adam White. An earlier version was published in *Journal of Regulatory Economics*, 2011, *40*(3), 303-323. This chapter is based on that version with new analyses and changes to earlier analyses.

[10] As noted in Federal Energy Regulatory Commission (FERC) (2010), Demand Response, or DR, "… refers to any scheme designed to encourage peak load reduction or load shifting away from peak demand periods – whether achieved through direct load controls (DLCs) such as air conditioner cycling programs, though interruptible tariffs, which allow a utility to cut off service during peak periods based on prior agreements, or through more sophisticated pricing schemes that offer financial incentives to consumers to reduce discretionary usage during critical hours."

curve becomes roughly vertical (Figure 1 in Appendix A)[11]. Therefore, a reduction in system demand from D_1 to D_2 – generated by demand response by industrials – may result in a considerable reduction in wholesale electricity prices and hence lower costs to *all* consumers.

The key consideration is whether the benefits of such a reduction will be offset by the corresponding increase in demand by industrials at some point in time. If the increase occurs during off-peak hours, or the elastic portion of the supply curve (D_3 to D_4 in Figure 1), then the resulting increase in price will be marginal. Consequently, the spillover benefits from lower demand or load reduction during peak hours will not be offset by equivalent increases in demand and higher prices in off-peak hours. If there is a strong offsetting effect, then society may be no better off than with Time of Use (TOU) or even flat rates.

This paper attempts to contribute to the literature by offering empirical magnitudes on the above relationships. First, we estimate elasticities of substitution between peak and off-peak hours with respect to electricity consumption by industrials; the value added from this exercise is that we use data based on all industrials in the province of Ontario that are directly connected to the transmission grid and are consequently exposed to Real Time Pricing. These elasticities are of policy importance, given the relatively thin empirical literature on the effects of RTP on electricity consumption by industrials; moreover, most studies are based on subsets of firms, rather than the universe of industrials enrolled in such programs. Our research is based on publicly available data (2005–2008), and some that were obtained on special request from the Independent Electricity Supply Operator (IESO) of Ontario. These data contain aggregate demand, wholesale prices (the Hourly Ontario Electricity Price, or HOEP), and specific hourly demand by six industrial sectors (2005–2007).

The use of Ontario data should be of interest to U.S. policy-makers, given similarities in the design of wholesale electricity markets in Canada and the United States as well as in the concentration of peak demand in the top 1 percent of hours.[12,13] Second, to the best of our knowledge this paper is the

[11] All figures and tables are in Appendix A.

[12] Competitive retail and wholesale electricity markets opened in May 2002 in Ontario. This changed on 9 December 2002 with the passage of the *Electricity Pricing, Conservation and Supply Act*, which capped the retail price of electricity for low-volume consumers. The amendment was in response to the significant spike in electricity prices and costs to consumers during the summer of 2002. The wholesale electricity market in Ontario remained competitive, with consumers such as industrial customers and LDCs submitting demand requirements and suppliers offering electricity generated by different types of fuel – including nuclear, coal,

first study to use an econometric model to evaluate the effects of shifts in demand by industrials on system-wide electricity prices in order to assess (1) benefits from potential demand response programs; and (2) whether such benefits might be attenuated as industrials shift their load away from peak hours. In contrast, most publicly available demand response studies rely on simulation methods.

Our estimates of elasticities of substitution from Generalized Leontief (GL) specifications suggest that, on aggregate, industrials shift demand between peak and off-peak periods. Specifically, a 10% increase in peak hour prices is, on average, significantly correlated with a 0.02%–0.07% increase in electricity consumption by industrials during off-peak hours. Further, the marginal effect of electricity load on the HOEP during peak hours for summer months exceeds the impacts of corresponding effects of demand during off-peak summer hours.

The above results offer evidence that while more electricity demand by industrials during off-peak hours is significantly correlated with higher wholesale prices, the magnitude of this effect is smaller relative to the corresponding impact of electricity consumption (of industrials) during peak hours. The important policy lesson is that changes in demand by industrials directly connected to the transmission grid have a stronger impact on the HOEP relative to demand by other consumers and can result in system-wide effects. This finding should be of interest given the 2007 *Energy Independence and Security Act* that directed the Federal Energy Regulatory Commission (FERC) to conduct a national assessment of demand response (DR) potential and to report to Congress.[14] In tandem, the above results confirm that RTP schemes give industrials an incentive to shift demand from peak to off-peak periods and therefore result in considerable benefits to all consumers.

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natural gas, and hydro. Bids are submitted to a clearing system managed by the province's Independent Electricity Supply Operator (IESO). However, final consumers pay prices that include other charges determined by the Ontario Energy Board (OEB). See Trebilcock and Hrab (2005) and Melino and Peerbocus (2008) for further institutional details.

[13] Faruqui, Hledik, Newell, and Pfeifenberger (2007) note that the top 80 to 100 hours account for roughly 11 and 16 percent of total demand in California and the PJM system. In Ontario, the top 32 hours account for 2,000 MW of demand out of a peak demand of 27,000 MW.

[14] The FERC was tasked to (1) provide an estimate of the national DR potential in 5–10 years; (2) estimate how much of the potential could be achieved; (3) identify barriers to their achievement; and (4) provide recommendations to overcome the barriers. See FERC (2009) for further details.

The remainder of our discussion is structured as follows. Section 2.2 offers a brief literature review. Section 2.3 discusses the data. Section 2.4 details our econometric model and estimable empirical specification. Our key findings are discussed in section 2.5. Section 2.6 concludes with a summary of our key findings.

2.2 Literature

Table 1 summarizes key papers that have estimated elasticities of substitution with respect to RTP programs and intra-day load shifting.[15] Our research differs from these papers for the following reasons. First, we are only aware of two papers (Boisvert et al., 2004; Boisvert et al., 2007) that have specifically estimated elasticities of substitution between peak and off-peak hours. Second, it is fair to say that most of the econometric literature on the effects of RTP schemes with respect to industrials has been restricted to select groups of firms that obviously choose to participate in such programs. The potential of self-selection bias has been noted in the literature (Herriges et al., 1993). Most studies have been unable to condition their estimates to such bias due to data unavailability of firms that do not enroll in RTP programs. Further, a majority of these papers are only able to employ data on a subsample of firms, rather than for all firms participating in RTP schemes.

We share a similar shortcoming with previous studies in that we do not have data on firms that are not directly connected to the transmission grid, which would enable us to pool information across firms and thus contrast differences in electricity consumption between participating and non-participating firms or industries. On the other hand, we do possess industry level electricity consumption data of all firms that are directly connected to the transmission grid. We think that there is also something to learn from using industry level data (across sectors), as it reveals (on average) behavior, which impacts the entire system. In this respect, we emphasize that the use of these data is the key feature that allows us to evaluate the impacts of dynamic pricing.

[15] Our review focuses on econometric based papers. Borenstein (2005), Borenstein and Holland (2005), and Holland and Mansur (2006) rely on simulations to estimate the gains to RTP schemes. There is, of course, literature on the effects of Time of Use (TOU) schemes on industrial customers and corresponding peak and off-peak elasticities. Schwarz, Taylor, Birmingham, and Dardan (2002) and Taylor, Schwarz, and Cochell (2005) offer comprehensive overviews. We also acknowledge studies that estimate residential, commercial, and industrial demand elasticities with data from Ontario during the 1980s and 1990s. These include Yatchew (2000), Mountain (1993), Mountain and Lawson (1992; 1995), and Ham, Mountain, and Chan (1997). However, these papers focus on the effects of TOU schemes.

Finally, to our knowledge, no study has used econometric models to evaluate the effects of load shifting by industrials on system wide wholesale electricity prices.[16] We did locate a relatively recent study conducted by The Brattle Group (2007) that was commissioned by PJM Interconnection LLC and the Mid Atlantic Distributed Resources Initiative (MADRI).[17] The study is based on simulation methods and finds that a 3% reduction in each selected zone's super-peak load reduces PJM's peak load by a little less than 1% and yields an energy market price reduction of $8–$25 per megawatt-hour. However, the authors of the study note that they do not consider several secondary effects that could offset the benefits to demand reduction. Specifically, they do not estimate the increase in prices that could occur if consumers shift load to other hours. Given the relative lack of studies, we think that an econometric-based approach to estimating the effects of demand by industrials on wholesale electricity prices should be of interest to policy-makers.

2.3 Data

The Ontario wholesale electricity market shares some features with deregulated electricity markets in New York and Pennsylvania-New Jersey-Maryland (PJM). The wholesale electricity market in Ontario is competitive, with consumers such as industrials and local distribution companies (LDCs) submitting demand requirements and suppliers offering electricity generated by different types of fuel, including nuclear, coal, natural gas, and hydro. Bids are submitted to a clearing system managed by the province's Independent Electricity Supply Operator (IESO). However, a key difference between the Ontario and U.S. markets is the existence of different prices across zones in the New York and PJM markets, which reflect local market clearing. On the other hand, the HOEP, the system wide wholesale electricity price in Ontario, is the result of market equilibrium of all bids and offers in the province.[18]

Data on the HOEP and corresponding market demand, hourly exports, and hourly imports of electricity are all publicly available data, which can be downloaded from the IESO website.[19] Hourly

[16] In terms of institutional details, Cappers, Goldman, and Kathan (2010) offer a comprehensive and contemporary overview of various DR programs across states.

[17] We are grateful to an anonymous referee for pointing us to this study.

[18] Retail prices paid by final consumers include wholesale prices and other charges determined by the Ontario Energy Board (OEB). Retail electricity rates are also regulated in many states in the U.S.

[19] As noted on its website (http://www.ieso.ca/imoweb/siteShared/whoweare.asp), the Independent Electricity Supply Operator (IESO) is a not-for-profit organization established in 1998 by the Electricity Act of Ontario.

demand by industry sector – total industry demand; iron and steel mills and ferro-alloy manufacturing; metal ore mining; motor vehicle manufacturing; petroleum and coal products manufacturing; pulp, paper and paperboard mills; electric power generation, and transmission and distribution (excluding local distribution companies, or LDCs) – were obtained on special request from the IESO.[20] These data consist of electricity consumption of industrials that are directly connected to the transmission grid and can thus react directly to the HOEP and benefit from dynamic pricing. The IESO also provided us with data on hourly supply by each generator in the province. These data contain not only details on firm affiliation but on the type of power, allowing us to capture the effects of market power among suppliers as well as control for the effects of different sources of electricity generation on an hourly basis.

Table 2 contains some descriptive statistics for electricity consumption by industrials during summer months (June, July, and August) from 2005 to 2008. Consumption by industrials that are directly connected to the transmission grid constitutes roughly 15–16% of total Ontario demand, a statistic that is consistent over time. Iron and steel mills, metal ore mining, and pulp and paper are the largest consumers, accounting for roughly 17% to just over 20% of total demand by industrials (connected to the grid).

Figure 2 offers some further insight into the relationship between wholesale prices (HOEP) and total demand by industrials. All the data are averaged across summer months for 2008.[21] The trends conform to intuition as industrials consume a significant amount of electricity during off-peak hours when prices are low, and reduce demand during high price period peak hours.

The IESO is basically responsible for monitoring and ensuring the efficient working of the Ontario electricity market. It connects all participants – generators, transmitters, retailers, industries and businesses that purchase electricity directly from the system, and local distribution companies (LDCs). All market participants must meet the standards enacted and enforced by the IESO.

[20] Some may find it surprising that we also analyze electricity consumption by electric utilities. However, as detailed in Table 2, their consumption is a non-trivial portion of demand by industrial customers connected to the transmission grid.

[21] This is a representative year. Data from other years are similar.

2.4 Econometric Model

2.4.1 Demand Elasticities by Industry

We use the model of industrial electricity response developed by Schwarz et al. (2002). The firm has to decide on the optimal allocation of electricity during peak (high price) and off-peak (low price) hours of the day. As noted by Boisvert et al. (2007), this approach is consistent with other studies that find that business customers bifurcate the day between peak and off-peak hours (Neenan, Boisvert, & Cappers, 2002; Neenan, Pratt et al., 2002) and accordingly choose business activity across different hours of the day.[22] Instead of conventional price elasticities of demand, we focus on elasticities of substitution (EOS) as the objective of the paper is to assess load shifting in response to peak and off peak price differentials. Following previous studies we use a Generalized Leontief (GL) cost function to model aggregate industry costs (C) relating to electricity consumption; [23,24, 25]

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[22] The discussion in this section is largely based on Boisvert et al. (2007) and Braithwait (2000).

[23] As noted by Boisvert et al. (2007), there are other flexible second-order functional forms that have been used in the literature. The Translog (TL) specification is one such common form, which has the advantage of being linear in parameters and not requiring information on aggregate electricity consumption as it relies on electricity cost shares. However, as pointed out by Caves and Christensen (1980a; 1980b) this model does not perform well when substitution elasticities are likely to be small, or with small shares or large differences among shares. In a seminal study, Patrick and Wolak (2001) find the TL model to perform poorly with respect to predicting residential customer demand response to real time pricing; they recommend the GL model, as an alternative. This is because the fixed coefficient Leontief technology can capture modest substitution possibilities. They use a Generalized McFadden (GM) model in their analysis, as their objective is to capture changes in consumption between hours within the same day, which allows them to acknowledge the possibility of positive as well as negative elasticities of substitutions. However, as noted by Boisvert et al. (2007), the assumption of two demand periods within the same day – as we do in our study by dividing the day into peak and off-peak periods - necessitates the assumption of a positive elasticity of substitution, which ensures global concavity (footnote 9, page 61). Therefore, like them, we rely on a GL rather than a GM specification.

[24] The use of homothetic GL cost function for individual firm is common in the literature. For example, see Boisvert et al. (2004, 2007). In this paper, we assume firm-level GL cost function with constant returns to scale, which satisfies the linear aggregation rule and give us an aggregate GL cost function based on a representative firm model. The use of a more general nonhomothetic GL cost function would result in an aggregate cost function that is dependent on the distribution of electricity consumption across firms. See Kim (2005) for a discussion of the aggregation properties of different flexible functional forms.

$$C = E(d_{pp}P_p^{\frac{1}{2}}P_p^{\frac{1}{2}} + d_{po}P_p^{\frac{1}{2}}P_o^{\frac{1}{2}} + d_{op}P_o^{\frac{1}{2}}P_p^{\frac{1}{2}} + d_{oo}P_o^{\frac{1}{2}}P_o^{\frac{1}{2}})\ , \qquad (1)$$

where E is effective electricity, P_p is peak price, P_o is off-peak price, and d_{pp}, d_{po}, d_{op}, and d_{oo} are parameters to be estimated. Specifically, d_{pp} (d_{oo}) is the marginal effect of a change in peak (off-peak) price on peak (off-peak) demand, while d_{po} (d_{op}) is the marginal effect of a change in peak (off-peak) price on off-peak (peak) demand. This function is linear homogenous in all prices, which is a requirement for a well-behaved indirect cost function. That is, if all prices are changed in the same proportion, then C changes in the same proportion as well. Following Shephard (1970), optimal (constant output) demand for peak and off-peak electricity can be obtained by differentiating (1) with respect to each price;

$$\partial C/\partial P_p = k_p = E\left|d_{pp} + d_{po}(P_p/P_o)^{\frac{1}{2}}\right|\ , \qquad (2)$$

$$\partial C/\partial P_o = k_o = E\left|d_{oo} + d_{op}(P_o/P_p)^{\frac{1}{2}}\right|\ . \qquad (3)$$

Berndt (1991) derives the Allen partial elasticities of substitution of the GL model as

$$\sigma_{op} = \left|Cd_{op}(P_pP_o)^{\frac{1}{2}}\right|/2\left|Ea_pa_o\right|\ , \qquad (4)$$

where $a_o = k_o/E$ and $a_p = k_p/E$. Equation (4) is the elasticity of substitution which measures the change in the ratio of daily peak to off-peak usage in response to changes in the off-peak to peak price. Assuming an additive error structure for the input cost equations a_o and a_p, it is possible to estimate the parameters of the GL model. However, E is an unspecified aggregate of peak and off-peak electricity use, and cannot be observed from the data. Following previous studies, and assuming separable within day electricity consumption, we use the ratio of the natural logarithm of a_p and a_o;

$$\ln\left|a_p/a_o\right| = \ln\left|k_p/k_o\right| = \ln\left\{\left|d_{pp} + d_{po}(P_p/P_o)^{\frac{1}{2}}\right| \Big/ \left|d_{oo} + d_{op}(P_o/P_p)^{\frac{1}{2}}\right|\right\}. \qquad (5)$$

[25] We could have also employed a simpler Constant Elasticity of Substitution (CES) specification as we divide the day into two time periods. However, for almost all years, Akaike-Schwartz and Bayesian Information Criterion values are much lower for GL models.

Denoting the estimated parameters of (5) as d^* and employing sample means of P_o and P_p, it is possible to obtain approximations of (C/E). Along with (5) and the estimated parameters d^*, the Allen partial elasticities of substitution can be derived as

$$\sigma_{op} = \left|(C/E)d^*_{po}\left(P_pP_o\right)^{\frac{1}{2}}\right|/2a_pa_o \ . \tag{6}$$

Further simplification of (5) yields an estimable non-linear specification

$$\ln\left|k_{p,it}/k_{o,it}\right| = \beta_0 + \ln\left\{\left|d_{pp} + d_{po}\left(P_{p,it}/P_{o,it}\right)^{\frac{1}{2}}\right| \Big/ \left|d_{oo} + d_{op}\left(P_{o,it}/P_{p,it}\right)^{\frac{1}{2}}\right|\right\}. \tag{7}$$

This is further modified as

$$\ln\left|k_{p,it}/k_{o,it}\right| = \beta_0 + \ln\left\{\left|d_{pp} + d_{po}\left(P_{p,it}/P_{o,it}\right)^{\frac{1}{2}}\right| \Big/ \left|d_{oo} + d_{op}\left(P_{o,it}/P_{p,it}\right)^{\frac{1}{2}}\right|\right\} + \beta_1 Temp_{it} + \sum Day_i + \sum Month_t + \varepsilon_{it} \ , \tag{8}$$

where *i* refers to the specific day in month *t* and ε_{it} is the error term, which is assumed to be independently and identically distributed. Consistent with the trends observed from figure 2, $k_{p,it}$ and $k_{o,it}$ are average hourly consumption in MWh during peak (7 am to 6:59 pm) and off-peak (7 pm to 6:59 am the next day) hours, respectively. Similarly, $P_{p,it}$ and $P_{o,it}$ are average daily prices in $/MWh during peak (7am to 6:59pm) and off-peak (7pm to 6:59am the next day) hours.[26] We estimate (8) for aggregate electricity consumption by all industrials as well as for the six sectors for which data are available for June, July, and August of each year from 2005 to 2008.

We also employ other controls. $Temp_{it}$ is the average daily temperature. Dummy variables for each day ($\sum Day_i$) are used to distinguish variation in electricity consumption across days during the week, which in turn reflects variation in industry output.[27] Dummy variables are used for July and

[26] There are studies (e.g., Taylor, Schwarz, and Cochell (2005)) that exploit variation across all hours, treating each hour as a separate electricity commodity, as opposed to aggregating hours according to peak and off-peak. However, as noted by Boisvert et al. (2004), there is evidence that some U.S.firms implicitly characterize the day as being composed of a peak and off-peak period (Goldman et al., 2004; Neenan, Pratt, Cappers, Boisvert, & Deal, 2002). This is certainly our understanding, based on conversations with industrial customers in Canada.

[27] What would be desirable are measures of actual industry output in dollars. However, we were unable to obtain such data, and are not aware of any other study that has managed to control for industry output. Taylor,

August as well in order to account for unobserved month specific shocks. Table 3 contains summary statistics.

Given the obvious potential for non-stationarity and correlation in electricity prices within the day, we first ran Dickey-Fuller tests for unit root and Gauss Newton Regression (GNR) tests for autocorrelation generated by up to an AR(4) process.[28] The Dickey-Fuller test was performed on the consumption ratios and the price ratios for total industrial and the 6 sectors across the four years. The results show that the null hypothesis of the existence of a unit root can be rejected in all cases. As for the GNR tests, using a testing down strategy, it is found that in most industries and years, there is evidence of serial correlation of order 1 in the error terms.[29] Therefore, consistent with previous studies (Herriges et al., 1993; Schwarz et al., 2002), we assume a first-order autocorrelation in the error term. Further, given the likelihood that the error term is correlated across industries, we use the nonlinear Seemingly Unrelated Regressions (NLSUR) methodology proposed by Gallant (1975). Specifically, we jointly estimate seven equations (total industrial demand and the six subsectors). Finally, following Braithwait (2000) and Boisvert et al. (2004; 2007), we impose the symmetry condition $d_{op} = d_{po}$ and the adding up constraint $d_{oo} + d_{op} + d_{po} + d_{pp} = 1$.[30]

2.4.2 Estimating the Effect of Load on the HOEP

The above discussion outlines our approach to estimating industry specific elasticities. The other contribution of this research is through our analysis of the effects of province specific demand on the Hourly Ontario Electricity Price (HOEP). The empirical specification that we employ is a standard reduced form expression:

Schwarz, and Cochell (2005) also use time dummy variables to control for variation in relative levels of output across these days.

[28] Please refer to Davidson and MacKinnon (2004), pp. 275-77, for further details on the test.

[29] Of the 28 industry-year combinations, the null hypothesis of an AR(4) error term cannot be rejected for Total Industrial in 2007, an AR(3) error term for Iron and Steel Mills and Ferro-Alloy Manufacturing in 2005, an AR(2) error term for Motor Vehicle Manufacturing in 2006 and Pulp, Paper and Paperboard Mills in 2008, and an AR(1) error term for 16 other industry-year combinations.

[30] The adding up constraint normalizes the parameters and imposing it only affects the estimates of $d_{oo}, d_{op}, d_{po}, d_{pp}$ but does not affect the elasticities of substitution.

$$P_{ijt} = \beta_0 + \beta_1 InDem_{ijt} + \beta_2 ODem_{ijt} + \beta_3 EXP_{ijt} + \beta_4 IMP_{ijt} + \beta_5 HHI_{ijt} + \beta_6 NUCP_{ijt} + \beta_7 COAL_{ijt} + \beta_8 HYDRO_{ijt} + \beta_9 GAS_{ijt} + \beta_{10} EXCHR_{jt} + \beta_{11} WEEKEND_{jt} + \beta_{12} HOLIDAY_{jt} + \beta_{13} Day_j + \sum h_i + \sum m_t + \varepsilon_{ijt} \ , \quad (9)$$

where *i*, *j*, and *t* refers to the specific hour, day and month respectively. The above model is a common methodology for evaluating the impacts of demand, costs, and market structure on observable energy prices in a given market.[31] P_{ijt} is the HOEP expressed in \$/MWh and is a function of electricity demand and usage of industrials directly connected to the transmission grid ($InDem_{ijt}$), electricity demand and usage of industrials not directly connected to the transmission grid, residences, and commercial establishments ($ODem_{ijt}$), exports (EXP_{ijt}), imports (IMP_{ijt}) and the mix of power supply between nuclear ($NUCP_{ijt}$), coal ($COAL_{ijt}$), hydro ($HYDRO_{ijt}$) and gas (GAS_{ijt}), all in MWh – in each hour *i* of day *j* in month *t*. By employing constructs for the source of electricity supply (nuclear, coal, hydro, or gas generated), we are not only controlling for the impacts of supply but also conditioning empirical estimates of load demand to whether the source of supply has differential impacts on electricity prices.

We also construct a Herfindahl-Hirschman Index (HHI_{ijt}) which is a measure of market power within an industry. Specifically, it is the sum of the square of the percentage of total electric supply generated by each individual firm for each hour.[32] Finally, we employ the average daily U.S.-Canada Exchange Rate ($EXCHR_{jt}$)[33] in order to capture the effects of macro-economic variables, and two dummy variables $WEEKEND_{jt}$ and $HOLIDAY_{jt}$ to capture the weekend and the holiday effects on

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[31] For example, with respect to gasoline prices, see Sen (2003) and Sen and Townley (2010).

[32] The Herfindahl-Hirschman Index (HHI) is the metric typically employed by antitrust agencies in different countries to measure industry-specific competitive effects or market structure and to identify and establish enforcement and investigative thresholds in the analysis of horizontal mergers. The HHI is quite easy to construct, being simply the sum of the squared market shares of firms, with market shares typically being constructed from firms' sales. Suppose that there are two firms supplying electricity, each of which supplies 50% of total market needs. The HHI in this case is (50 x 50) + (50 x 50) = 5000.

[33] The use of aggregate variable such as daily exchange rate in the analysis of hourly data may results in the OLS standard errors that are seriously biased downward (Moulton, 1990) as the error term cannot be assumed independent with the same day. One approach is to use standard errors clustered by day. Instead of cluster standard errors, our use of HAC standard errors with Bartlett kernel and a bandwidth of 24 (=2 days) should also help to alleviate the problem.

electricity use. Day_j is simply the day of the month and is intended at reflecting the effects of trends within the month. Dummy variables are constructed for each hour ($\sum h_i$) and month ($\sum m_t$) in order to control for the potentially confounding effects of other time specific unobserved determinants of wholesale electricity prices.

Equation (9) is estimated by Ordinary Least Squares (OLS) and the Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors with Bartlett kernel and a bandwidth of 24 are used to correct for the impacts of possible heteroskedasticity and autocorrelation in the error term. We use a levels specification, based on results from Likelihood Ratio tests (from Box-Cox regressions) that do not reject the use of a levels specification equation (9). We did not obtain any difference in our results by clustering the standard errors by hour or day, and these results are omitted for the sake of brevity. Summary statistics are in Table 3. Finally, we note that unlike the case with demand elasticities, our estimates of the effects of demand on price are derived from 2005, 2006, and 2007 (summer months) data, as this is the time span of generator specific supply that we obtained from the Independent Electricity Supply Operator (IESO).

2.5 Results

2.5.1 Demand Elasticities by Industry

Table 4 contains nonlinear SUR estimates of the key parameter d_{po} (from equation (8)), which is the foundation for the partial Allen elasticity of substitution.[34] We estimate equation (8) using demand data for all industrials and all the six sectors (iron and steel mills and ferro-alloy manufacturing; metal ore mining; motor vehicle manufacturing; petroleum and coal products manufacturing; pulp, paper and paperboard mills; electric power generation; transmission and distribution). Further, we conduct estimates for each year (2005 to 2008) in order to assess possible changes over time. As discussed above, econometric estimates are based on year-specific samples over summer months (June, July, and August) with hourly prices and demand averaged across peak (7am – 6:59pm) and off-peak (7pm – 6:59am) hours. Therefore, each day has a single observation. Finally, we report heteroskedasticity consistent standard errors.

[34] Consistent with the literature, we focus on the cross-price effect (d_{po}) between peak and off-peak consumption. Complete results are available on request.

The first key finding is that, on average, estimates of d_{po} with respect to total demand by all industrials are statistically significant (at either the 10%, 5%, or 1% levels) across most columns. In contrast, there is considerable variation in estimates across specific industries and over time. Specifically, d_{po} is always statistically insignificant for most years for the metal, iron and steel, and motor vehicle industries.[35] However, estimates with respect to demand by petroleum and the pulp and paper industries are statistically significant for most years. Specifically, the estimate of d_{po} with respect to the petroleum industry are significant for 2006, 2007, and 2008 and ranges from 0.02 to 0.04. The corresponding estimates for the pulp and paper industry are significant for all years except for 2007, ranging from 0.02 to 0.05.[36] Finally, only the 2008 estimate for electricity power and generation is statistically significant.

Table 5 contains estimates of the elasticities of substitution that correspond to the above results (based on equation (8)). Standard errors were estimated using the recursive-design wild bootstrap method developed by Goncalves and Kilian (2004), which also produces bias-corrected 95% confidence intervals. With respect to total consumption by all industrials, the results yield elasticities of substitution from 0.02 to 0.065. Elasticities of substitution for the petroleum and coal products industry range from 0.045 to 0.07. The highest elasticities are for the pulp and paper industry and are between 0.05 and 0.10. In summary, our estimates of elasticities of substitution are slightly lower in magnitude than the 0.08-0.18 range suggested by previous studies. This is likely due to the fact that previous studies usually include voluntary participants of RTP scheme and therefore those who are more flexible in their production process to take advantage of RTP by load shifting are more likely to be self-selected into the sample. In contrast, in Ontario, all customers who are connected to the transmission grid are required to participate in the market, regardless of their ability to load shift.

[35] These estimates are available on request.

[36] These findings correspond to intuition offered to us by industry experts associated with the Association of Major Power Consumers of Ontario (AMPCO), an organization representing energy policy interests of major industrial customers in the province. The pulp and paper industry is supposed to be relatively flexible in terms of with- and across-day operations and has the capability to adjust operation hours in order to reap the benefits of lower prices during off-peak hours. On the other hand, the petroleum industry in Ontario is quite concentrated and dominated by a few firms. Apparently most of these firms possess internal generators that may be used if the HOEP becomes too expensive. So while they do have the ability to shift consumption during off-peak hours, our results probably also reflect the shift towards internal energy production and consumption during high price hours.

2.5.2 Estimating the Effect of Load on the HOEP

The above results offer evidence that some industries do shift consumption over hours in order to reap the benefits of lower electricity prices. The next question is whether there are differences in the effects of overall demand on the hourly electricity price. A larger marginal effect during peak hours would suggest that the benefits of reduced consumption during peak periods will not be offset by a corresponding increase over off-peak hours. Further, differences in coefficient estimates of demand by consumers would reveal whether industrials directly connected to the transmission grid have an independent and direct effect on the HOEP. Table 6 and Table 7 contain Ordinary Least Squares (OLS) and second stage Instrumental Variables (IV) estimates (with HAC standard error estimates) of equation (9) with respect to peak and off-peak hours, respectively.

The IV results allow us to evaluate the possibility of measurement error in single equation estimates of electricity demand by industrials, arising from simultaneity bias. This is important given our findings from GL models specifications.[37] We employ two hour lagged demand by industrials and the hour specific average daily temperature in Toronto as instruments for electricity demand by industrials. The use of two hour lagged demand assumes the existent of a correlation in hourly demand within the same day and that lagged demand should not directly affect current price.[38] With respect to our second instrument, an increase in temperature should be associated with more electricity demand, all else being equal.

In almost all specifications, both instruments are positive and statistically significant (at either the 1% or 5% levels), confirming that electricity demand by industrials increases with temperature and is also correlated with demand in earlier hours. For the sake of brevity, we only report the *F* statistics from joint tests of significance, which demonstrate that we can comfortably reject the null hypothesis that the coefficient estimates of the instruments are equal to zero. The results of overidentification test

[37] Simultaneity bias could also exist in equation (8) or between price and non-industrial consumption. Regarding the former, we attempted IV estimation but were not able to get convergence in our estimation due to the highly nonlinear nature of the model specification. The load shifting behavior of the industrial customers is further explored in the next chapter and IV estimation is applied to a linear model specification to correct for possible simultaneity bias. Regarding the latter, we argue that since customers not connecting to the transmission grid do not face the HOEP hourly, the HOEP should not directly drive their consumption decision.

[38] We also used five and six hour lagged demand as instruments in order to test the sensitivity of our results. We obtained very similar estimates.

however shows that at least one instrument might be correlated with the error terms in the peak period analysis for 2005 and 2007 and the off peak period analysis for 2005. The IV estimates should therefore be interpreted with caution. Detailed first stage estimates are available on request.

OLS and IV estimates in Table 6 and Table 7 are quite similar, suggesting the absence of significant simultaneity bias. Table 6 demonstrates that a 1000 MWh reduction in demand by industrials during peak hours is significantly associated (between 10% to 1% levels) with roughly a \$20–\$50 drop in the HOEP. On the other hand, a 1000 MWh reduction in demand by other consumers is correlated with a \$17–\$27 fall in the HOEP. In terms of other estimates, exports (imports) is positively (negatively) and significantly correlated (at the 1% level), with higher price. The one source of power generation that is significant (at the 1% level) across all columns is nuclear electricity, which possesses negative signs across all columns. Coefficient estimates of weekend and holiday dummy variables are positive and statistically significant (at the 10% or 1% levels) across all columns, possibly capturing the effects of increased load demand by residences.

Results contained in Table 7 offer some further evidence on the curvature of the elastic supply curve through empirical estimates of the effect of demand by industrials and other consumers on the HOEP during off-peak hours. The first observation is that coefficient estimates of industrial demand as well as demand by others are smaller in magnitude relative to estimates in Table 6. The estimates indicate that a 1000 MWh increase in demand by industrials during off-peak hours is significantly associated (between 10% to 1% levels) with a \$9–\$25 increase in the HOEP. In contrast, a 1000 MWh increase in demand by other consumers during off-peak hours is significantly correlated (between 10% to 1% levels), on average, with a \$6–\$20 increase in the HOEP. The estimates of other covariates are otherwise comparable to those in Table 6.

In summary, results contained in Table 6 and Table 7 suggest that hourly demand by industrials have a stronger impact on the HOEP relative to other consumers. The estimates in Table 6 also reveal that hourly demand by industrials has a larger marginal effect on the HOEP during peak (relative to off-peak) hours.[39] Therefore, a price reduction from lower industrial demand during peak hours should not be offset by a corresponding increase in demand during off-peak hours.

[39] With respect to all the regressions in Tables 6 and 7, we used F tests to evaluate the null hypothesis that coefficient estimates of demand by industrial customers are larger in magnitude than coefficient estimates of demand by other consumers. In most cases, we could not reject the null hypothesis.

2.6 Conclusion

The late 1990s and early 2000s witnessed considerable deregulation of electricity markets in North America. Sudden and sharp increases in retail prices accompanied by overall price volatility, as well as sudden blackouts, resulted in the imposition of price ceilings in California and Ontario still in effect today. Many states continue to regulate electricity prices. However, competitive wholesale markets exist alongside regulated retail sectors. The inability to allow retail prices to reflect changes in wholesale price shocks causes considerable market distortions and inefficiencies. As a result, focusing on the incentives to industrials and their impact on wholesale prices has assumed key policy importance.

This paper attempts to fill this gap by employing data for summer months from 2005 to 2008 for the province of Ontario. Using data over multiple years enables us to assess the sensitivity of our findings to year-specific shocks. Data obtained on special request from the IESO allows us to evaluate the effects of price on consumption across different industries. We obtain elasticities of substitution from 0.02 to 0.07, with considerable heterogeneity across industries. While these results are on the lower end of corresponding estimates from other papers, there are plausible explanations for our estimates. For example, as discussed earlier, most studies are based on sample of firms that voluntarily decide to enroll in RTP programs and are therefore more likely to engage in load-shifting than non-participating firms. They are unable to employ data on the universe of firms participating in such programs. In contrast, we use data on all firms that are connected to the transmission grid. Therefore, we interpret our estimates as modest evidence that industrials do shift consumption from peak to off-peak hours in order to exploit the benefits of lower prices during those times.

We also find that lower market demand by industrials during peak hours is significantly associated with a decline in the HOEP. On the other hand, the marginal impact of an increase in demand during off-peak hours is of a much smaller magnitude. Coefficient estimates of the effects of demand by industrials are larger in magnitude than corresponding estimates with respect to demand by other consumers. We think this to be an important finding, given the lack of econometric evidence and the inability of recent simulation based studies to account for such offsetting effects.

In tandem, these results offer support to the notion that policies that encourage efficient demand management by industrials will result in positive spillovers to all consumers. A good example would be the implementation of higher network transmission charges (for industrials) during peak hours. For example, Hydro One Networks Inc. (HONI), a corporation owned by the Government of Ontario, is responsible for the planning, construction, operation, and maintenance of most (97%) of the province's transmission and distribution network, which carries electricity from generating stations to local distribution companies and industrial customers. Currently, HONI bases network transmission charges for individual customers on their respective demand level, calculated each month as the higher of (1) the customer's demand at the time of the monthly coincident peak demand, or (2) 85% of the customer's maximum non-coincident demand between 7:00am and 7:00pm on weekdays that are not holidays.

As evident, this system offers limited consumer benefits for shifting consumption away from the month specific peak demand and provides little incentive for efficient demand management for shifting consumption from peak to off-peak hours. More response could potentially be achieved through higher network charges during peak hours. The potential for cost savings from even small reductions in peak demand are enormous. Faruqui et al. (2007) estimate that even a 5 percent drop in peak demand may result in significant savings in generation, transmission, and distribution costs of $3 billion a year. The implication of our study is that policies focused on industrials may achieve such savings.

Chapter 3

Real Time Price Elasticities of Electricity Consumption: Evidence from Industrial Customers in Ontario

3.1 Introduction

The Ontario Legislature passed the Green Energy Act in May 2010, initiating several programs intended at encouraging efficient demand response through Real Time Pricing (RTP). An unregulated market accomplishes this efficiently, as consumers would respond to higher prices by reducing electricity use during periods of scarcity.[40] However, consumers in Ontario currently have extremely limited incentive to react to higher peak time prices given the quasi-competitive nature of electricity markets. Specifically, while the wholesale market is competitive, retail prices paid by residences and commercial establishments are capped and set by the Ontario Energy Board (OEB). These customers obtain their electricity through Local Distribution Companies (LDCs) and enjoy limited savings from reduced use during peak hours.[41]

On the other hand, significant benefits may emerge through schemes that yield incentives for industrials – the largest consumers of electricity – to shift production from peak to off peak hours. As many industrials are directly connected to the transmission grid, this could take the form of differences in transmission charges between peak and off-peak hours.[42] Higher network transmission

[40] A benefit of competitive markets is the implementation of Real Time Pricing (RTP) whereby consumers are directly exposed to prices that change on an hourly basis and can adjust their consumption correspondingly. Specifically, RTP schemes incent consumers to reduce their demand during peak hours with higher prices to off-peak periods with lower prices. These schemes result in efficient incentives as they reduce cross-subsidization that occurs to consumers that use a large amount of electricity during hours with high prices. This principle is consistent with Ramsey Pricing, in the sense that individuals who still consume during peak hours are those with the most inelastic demand, and should be 'taxed' the most. In terms of recent U.S. research, Borenstein (2005), Borenstein and Holland (2005), and Holland and Mansur (2006) rely on simulations to estimate the gains to RTP schemes.

[41] Please see Trebilcock and Hrab (2005) and Melino and Peerbocus (2008) for further institutional details regarding the Ontario electricity market.

[42] For example, Hydro One Networks Inc. (HONI) and all transmission providers in Ontario, currently base network transmission charges for each customer based on their respective demand level calculated each month

charges during peak hours give industrial consumers an incentive to shift their demand to off peak hours. Load shifting by industrials could theoretically benefit all consumers (residential, commercial, and industrial) through a reduction in overall system demand and consequently, in wholesale electricity prices (the Hourly Ontario Electricity Price – or simply 'HOEP').

In order to investigate the existence of such behavior, it is necessary to estimate overall demand price elasticities for the industrial sector. We accomplish this by employing publicly available data (2005-2008) – as well as some that were obtained on special request from the Independent Electricity Supply Operator (IESO) of Ontario. These data contain aggregate demand, wholesale prices (the HOEP), and specific hourly demand by industrial sector (from 2005 to 2007) – total demand by all industrials, pulp and paper, iron and steel mills and ferro-alloy manufacturing, metallic ore mining, petroleum and coal products manufacturing, motor vehicle manufacturing, and electricity power generation, transmission, and distribution. We use the data to estimate the effects of HOEP on demand by industrial sector.

Both Ordinary Least Squares (OLS) and Instrumental Variables (IV) estimates show that some industrials reduce their demand in response to higher prices. The IV estimates are in general slight larger than the OLS estimates in magnitude. Specifically, our IV results suggest that a 10% rise in the HOEP is significantly associated with a 0.8-1.5% drop in industrial demand. Perhaps more importantly, coefficient estimates of lagged electricity prices are statistically significant for most industries – implying that even in the absence of any strong regulatory incentive - firms are responsive to wholesale price signals and do shift demand between peak and off peak periods.

We view our research as a contribution to the rather sparse literature on the effects of real time wholesale electricity prices on demand by industrials. First, a majority of studies are based on samples of firms that choose to self-select in RTP schemes, raising the possibility of bias from specific characteristics associated with such firms.[43] In contrast, we are able to employ aggregated

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as the higher of: (1) The customer's demand at the time of the monthly coincident peak demand, or; (2) 85% of the customer's maximum non-coincident demand between 7:00 A.M. and 7:00 P.M. on weekdays that are not holidays.

[43] Recent studies on industrial demand elasticities based on real time pricing in the U.S. are Herriges et al. (1993), Schwarz et al. (2002), Taylor et al. (2005), Hopper, Goldman, and Neenan (2006), and Boisvert et al. (2004; 2007). Most of these studies employ small samples of industrial customers. However, Patrick and Wolak

data of all industrials that are directly connected to the transmission gird and are able to respond to changes in real time wholesale prices. Third, most of these papers do not focus on responses (by industrials) to peak-off peak prices differentials.[44] Third, we view our use of instrumental variables (IV) estimation to be an important distinguishing feature of this study. We are not aware of many other relevant papers that have similarly assessed the magnitude of measurement error in coefficient estimates of electricity price on demand by industrials.[45] Fourth, this study should also be useful to policymakers in Canada given the relatively limited number of papers on demand elasticities and pricing after deregulation in Ontario and Alberta.[46] Our reliance on more recent data should benefit policymakers as it reflects the contemporary structure of electricity markets. Finally, we employ data over a considerably long period of time, which enables us to control for the potentially confounding effects of time-invariant structural or policy shocks.

3.2 Data

Data on the HOEP and corresponding market demand, hourly exports and imports of electricity are all publicly available data, which can be downloaded from the website of the Independent Electricity

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(2001) exploit a large sample of firms from England and Wales. Please refer to Boisvert et al. (2007) for an overview of relevant U.S. based studies. Lijesen (2007) contains a comprehensive of other international studies.

[44] To the best of our knowledge, only Boisvert et al. (2004; 2007) investigate the effects of real time changes in price on shifts between peak and off peak consumption by industrials. Most of the literature on such shifts, are based on within day Time of Use (TOU) fixed rates. As a result the data are older and from time periods before the deregulation of electricity markets. Lijesen (2007) contains a nice overview of these papers. Studies that estimate demand elasticities with data from Ontario during the 1980s and 1990s include Yatchew (2000), Mountain (1993), Mountain and Lawson (1992; 1995), and Ham, Mountain, and Chan (1997). In terms of more recent research, Angevine and Hrytzak-Lieffers (2007) investigate the effects of price on consumption by industrials during the 2002-2003 and 2006-2007 and estimate separate price elasticities for peak and off peak periods. However, they do not estimate the effects of lagged prices, which we do in this study. Melino aand Peerbocus (2008) investigate the effects of Ontario price shocks on export and import volumes.

[45] An exception is Lijesen (2007), who employs 2003 system wide hourly price and demand data from the Netherlands.

[46] Electricity generation, transmission, and distribution in most provinces is accomplished through vertically integrated Crown Corporations, which are also monopolies. Alberta and Ontario are the only two provinces that have enacted varying degrees of privatization. Alberta’s move to deregulated markets began in 1996 while competitive retail and wholesale markets opened in Ontario in 2002.

Supply Operator (IESO) of Ontario.[47] Hourly demand by industry sector – total industry demand, iron and steel mills and ferro-alloy manufacturing , metal ore mining, motor vehicle manufacturing, petroleum and coal products manufacturing, pulp, paper and paperboard mills, electric power generation, transmission and distribution (excluding local distribution companies (LDCs)) – were obtained on special request from the IESO. These data consist of electricity consumption of industrials that are directly connected to the transmission grid and can thus react directly to the HOEP. The IESO also provided us with data on hourly supply by each generator in the province. These data not only contain details on firm affiliation, but the type of power, allowing us to control for the effects of different sources of electricity generation on an hourly basis.

Table 2 contains some descriptive statistics for electricity consumption by industrials during summer months (May, June, July, and August) from 2005-2008. Consumption by industrials that are directly connected to the transmission grid constitutes roughly 15-16% of total Ontario demand – a statistic that is consistent over time. Iron and steel mills, metal ore mining, and pulp and paper are the largest consumers, accounting for roughly 17% to a bit over 20% of total industrial demand.

There is significant variation in electricity consumption across industries. Figure 3 demonstrates that consumption by iron and steel mills drops during early peak hours, but then climbs thereafter. On the other hand, demand by metal ore mining is considerably lower during peak hours. Consumption by motor vehicle manufacturing correlates positively with the HOEP – probably due to the fact most production usually occurs during regular workday hours. In contrast, demand by petroleum and coal products manufacturing is relatively constant across time. On the other hand, average demand by pulp and paper mills and electricity power generators, transmitters, and distributors quite clearly demonstrate an inverse relationship with the HOEP.[48]

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[47] As noted on its website (http://www.ieso.ca/imoweb/siteShared/whoweare.asp), the Independent Electricity System Operator (IESO) is a not-for-profit organization established in 1998 by the Electricity Act of Ontario. The IESO is basically responsible for monitoring and ensuring the efficient working of the Ontario electricity market. It connects all participants – generators, transmitters, retailers, industries and businesses that purchase electricity directly from the system, and local distribution companies (LDCs). All market participants must meet the standards enacted and enforced by the IESO.

[48] These trends correspond with 2003 data on electricity costs as a percentage of total operating costs that were obtained on special request from Statistics Canada. Specifically, information from the Annual Survey of Manufacturers reveals that electricity costs of the following magnitude: Pulp, Paper and Paperboard Mills

3.3 Estimation Methodology

Consistent with Lijesen (2007), who also employs aggregate system data (from the Netherlands), we employ a log-log specification based on standard consumer theory;[49]

$$\ln K_i = \beta_0 + \beta_1 \ln P_i + \beta_2 \ln P_j + Z + \varepsilon_i \; . \qquad (10)$$

Average electricity usage or consumption during a specific time period i or consumption (K_i) is a function of average wholesale prices in that period (P_i) as well as other time periods (P_j).[50] ε_i is the error term, which is assumed to be independently and identically distributed. If Z succeeds in controlling for income shocks, then β_1 and β_2 are compensated price elasticities.

We estimate equation (10) employing variation across peak and off peak prices and aggregate Ontario demand from 2005-2008. The hours are broadly divided into peak (7 am to 6:59 pm) and off peak (7 pm to 6:59 am the next day). Consumption is assumed to be a function of average prices during the specific time period (P_i) as well lagged prices (P_j). Hence, when the data refers to electricity consumption during *peak* hours (7 am to 6:59 pm), the lagged price is average *off peak* prices from 12 am to 6:59 am of the same day, but earlier in the morning. On the other hand, when K_i is electricity consumption during *off peak* hours (7 pm to 6:59 am the next day), the lagged price is average *peak* price between 7 am to 6:59 pm of the same day, reflecting the effects of electricity substitution *across* days. In both cases, if there is substitutability, then β_2 will still be positive.

(4.97%); Iron and Steel Mills and Ferro-Alloy Manufacturing (8.40%); Metal Ore Mining (6.10%); Motor Vehicle Manufacturing (1.04%); and Petroleum and Coal Products Manufacturing (0.94%).

[49] Many other studies based on different types of data also employ log-linear models or specifications based on such models to estimate electricity price elasticities. For example et al., Alberini, Gans, and Velez-Lopez (2011) use energy utility data for over 69,000 single-family homes and duplexes (74,000 households) in the 50 largest metropolitan areas in the US for 1997–2007.

[50] There may be an argument that the price paid by a firm is the sum of the HOEP and the Global Adjustment (GA). As noted by the IESO website, the Global Adjustment (GA) is the difference between the total payments made to certain contracted or regulated generators/demand management projects, and any offsetting market revenues. However, the GA is a month end adjustment to electricity bills and does not vary by hour. Further, for the sample period we study, the GA Is not significant relative to the HOEP. Please see http://www.ieso.ca/imoweb/b100/b100_GA.asp for further details.

Further, we are effectively constraining the demand elasticity of peak demand with respect to off peak price and the demand elasticity of off peak demand with respect to peak price, to be the same.

There is an important caveat to the interpretation of β_2. A statistically significant relationship between lagged prices and current demand might reflect some degree of market inertia, with price shocks in some hours having some residual effects over a longer time period. However, the implication also is that industrials have some ability to forecast changes over a relatively short time period, and accordingly adjust demand in order to exploit benefits from lower prices that would occur later in the day. This is certainly a reasonable assumption given the availability of day ahead price forecasts from the IESO and general weather forecasts.

Z captures the potentially confounding effects of other unobserved factors that impact industry profitability and therefore affect electricity consumption. Dummies are used to distinguish variation in electricity consumption during weekends and non-weekend holidays. We will also alternatively employ month specific dummies and month specific unemployment rates, and the daily Canada/U.S. exchange rate.

We also construct a variable (Toronto cooling degree days) that takes a value of 0 if the Toronto hour specific temperature is less than or equal to 24 degrees Celsius, and the (actual Toronto temperature) – (24 degrees Celsius), otherwise. This 'Toronto Cooling-Degree Days' variable is included as a covariate because of the impact of temperature, in general, has on the demand for electricity. This covariate is motivated by the "air conditioning" argument, which implies that higher temperature in Ontario directly increases demand in all sectors, including the industrial sector.

Given the obvious potential for non-stationarity and correlation in electricity prices within the day, we ran Dickey Fuller tests for unit roots and Breusch-Godfrey Lagrange Multiplier tests for first order autocorrelation. The Dickey Fuller test results show the null hypothesis of the existent of a unit root cannot be rejected in most of the consumption and price time series.[51] The Breusch-Godfrey Largrange Multiplier test results show that the null hypothesis of no first order autocorrelation can be rejected in all specifications. Therefore, the estimation methodology is Ordinary Least Squares (OLS) for coefficient estimates, and Heteroskedasticity and Autocorrelation Consistent (HAC) standard

[51] The exceptions are consumption by metal ore mining in 2006, and consumption by petroleum and coal products manufacturing in all years from 2005 and 2008. As non-stationarity might lead to spurious results, the estimates for these industries in these years should be interpreted with caution.

errors with Bartlett kernel and a bandwidth of 24 to account for the impact of heteroskedasticity and autocorrelation on OLS standard errors. Comparable results were obtained by clustering standard errors by day of month in order to account for unobserved correlations that are day specific or across days, and are available on request. Table 8 contains summary statistics.

3.4 Empirical Results

3.4.1 Demand Elasticities by Industry

Table 9 contains benchmark OLS estimates of lagged and contemporaneous prices on demand by industry conditioned on month specific dummies. We econometrically estimate the relationship between demand and price for each year (2005-2008) in order to assess possible changes over time. As discussed above, econometric estimates are based on year specific samples over summer months (May, June, July, and August) with hourly prices and demand averaged across peak (7 am – 6:59 am) and off peak (7 pm – 6:59 am) hours. Therefore, each day has two observations, enabling us to exploit within as well as across day variation over a period of four months.

The first key finding is that, on average, total demand by all industrials (panel A) are impacted by contemporaneous prices. Specifically a 10% increase in hourly prices is significantly correlated with a roughly a 0.5 –0.8% fall in demand (in most columns) – a result that is statistically significant at the 1% level. We obtain estimates from -0.02 to -0.06 with respect to the iron and steel industries (panel B) and metal (panel C). The coefficient estimate of current prices is even larger with respect to the pulp and paper industry (panel F). Our estimates suggest that a 10% increase in electricity prices is significantly associated (at the 1% level of significance) with a 1.2-2.5% decline in electricity demand by the pulp industry. However, while coefficient estimates of current prices with respect to demand by petroleum and coal products are also statistically significant across most columns, the sign is positive for 2005 and 2007 and negative for 2006 and 2008. Similarly, coefficient estimates of price for demand by motor vehicle manufacturing are statistically significant – they possess a positive sign. However, these results correspond with the intuition suggested by the figures. Electricity demand by petroleum and coal products seems to be time invariant, while the positive correlation between the HOEP and consumption by motor vehicle manufacturing reflects production that follows a typical work day schedule.

What is perhaps even more intriguing is that coefficient estimates of average prices in the previous 12 hours is significantly correlated with an increase in *contemporaneous* hourly demand across all industries for most years – suggesting that industries do shift demand across peak and off peak periods. Further, the magnitudes of coefficient estimates are remarkably consistent across industrial sector. Empirical estimates imply that a 10% increase in average prices 12 hours ago is significantly associated with a roughly 0.1-1.5% increase in current consumption by all industrials, iron and steel mills, metal ore mining, motor vehicle manufacturing, and petroleum and coal products manufacturing, controlling for the effects of other factors. On the other hand, demand elasticities for pulp and paper and electric power generation are even larger in magnitude relative to other industries– ranging from -0.09 to -0.3. These findings are statistically significant at either the 5% or 1% levels of significance.[52]

Table 10 offers some sensitivity analyses by replicating the results in Table 9. The only difference is that we use the month specific unemployment rate, daily Canada-U.S. exchange rate, and holiday and weekend dummies, instead of month dummies.[53] The use of these covariates allow us to specifically capture variation in economic and other unobserved shocks experienced by industries.

Our results remain unaltered. In the first four columns, a 10 % increase in current prices is significantly correlated with approximately a 0.2-0.5% drop in demand by all industrials, iron and steel mills, and metal ore manufacturing. While coefficient estimates of prices for motor vehicle manufacturing and petroleum and coal products manufacturing are either statistically insignificant or possess the wrong sign, demand elasticities with respect to pulp and paper and electricity are larger (-0.10 to -0.4). These findings are consistent with Angevine and Hrytzak-Lieffers (2007). As before, coefficient estimates of lagged prices are in many cases statistically significant (at the 1% or 5% levels), with larger effects for pulp and paper and electricity transmission, generation, and distribution.

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[52] These estimates are not inconsistent with findings from previous studies. For example, Ham, Mountain, and Chan (1997) analyze the 1985 Ontario Hydro experiment which studied the effects of time of use (TOU) on small commercial customers. They find peak elasticities ranging from -0.091 to -0.067 for various appliances. They also obtain aggregate statistically significant own-price elasticities for total electricity usage (-.134 in the winter and -.114 in the summer). These elasticities are slightly higher than those suggested by Mountain (1993), with respect to the residential sector (-.12 in the winter and -.09 in the summer).

[53] Again, instead of using standard errors clustered by month or day to correct for possible downward bias in OLS standard errors due to the use of aggregate variables such as monthly unemployment rate and daily exchange rate, we use HAC standard errors with Barlett kernel and a bandwidth of 24 (= 12 days) to alleviate the problem of correlated error terms within a month or a day.

3.4.2 Instrumental Variable Estimation

Our empirical specification assumes that changes in prices exogenously affect demand. However, shifts in demand due to factors other than price - will impact equilibrium prices. An inability to account for these factors will result in a correlation between the coefficient estimate of price and the right hand side error term, leading to confounded results and flawed inference. The challenge is to locate an instrument that might plausibly affect variation in Ontario prices and yet remain uncorrelated with the right hand side error term.

We propose to evaluate the sensitivity of our findings by employing the difference between New York and Toronto hourly temperatures as an instrument for the Hourly Ontario Electricity Price (HOEP). Specifically, we construct a similar "cooling days" covariate for New York, as we did for Toronto, which takes a value of 0 if the New York hour specific temperature is less than or equal to 24 degrees Celsius and the (actual New York temperature) – (24 degrees Celsius). The specific instrument is then the difference between these two "cooling day" variables (New York – Toronto) for each hour. The rationale for this instrument is that, other things being equal, when New York City is warmer than Toronto, demand for electricity in New York increases, which pushes up the price of electricity in New York relative to the price in Ontario. More electricity is then exported to New York from Ontario, reducing supply in Ontario and raising the price in Ontario. Therefore, our instrument exploits variation in the HOEP induced by these supply shocks that are a result of temperature differentials between NYC and Toronto.

The instrument also allows us to accommodate possible non-linearities in the relationship between temperature and the summer demand for electricity, and is consequently more flexible then using the simple difference in temperatures between the two cities. Specifically, it is believed that most people set their air conditioner's thermostat at some temperature, say 24˚C, below which the air conditioner will stay off. Therefore, the impact of temperature on the demand for electricity to power air conditioners is much less when the temperature is below 24˚C. The "cooling days" covariates with base 24 are used to model this nonlinear relationship.[54] Employing this instrument is also consistent with previous studies that have noted the extensive trade in electricity between Ontario and New

[54] We also used other bases such as 22 and 26 and obtained similar results.

York.[55] However, demand in either of these markets should not be directly affected by the difference between each other's temperature.

To a lesser degree, the lag of the HOEP, could also conceivably be endogenous if firms determine the allocation of peak and off-peak period consumptions jointly. Based on a similar argument as discussed above, we use the lag of the difference in New York's and Toronto's cooling degree days, as well as the lag of Toronto's cooling degree days as instruments. The use of three instruments for two endogenous regressors will allow us to test the validity of the instruments.

Table 11 presents first stage regressions for each year. The instrument (NYC minus Toronto's cooling degree days) is significantly correlated (at the 1% level) with an increase in the HOEP for all years. The lag of (NYC minus Toronto's cooling degree days) and the lag of Toronto's cooling degree days are also positively correlated with the lag of the HOEP at the 1% significant level. Further, in most cases, the *F* statistics from the joint test of significance (of the null hypothesis that the coefficient estimates of the instruments are equal to zero) comfortably exceed the value of 10, suggested by Staiger and Stock (1997).

Table 11 also contains corresponding second stage estimates. To test the validity of all instruments, a Hansen J statistic is computed for each specification. A large Hansen J statistic indicates strong evidence to reject the null hypothesis that all instruments are uncorrelated with the error term. In general, the test results show that the null hypothesis of valid instruments cannot be rejected at the 5% significant level in most specifications. The exceptions are metal ore mining in 2005 and petroleum and coal products manufacturing in 2005.[56] Both the test of relevance and the overidentification test suggest that the three instruments are valid in most cases.

Provided that the instruments are valid, a test of endogeneity can be done for the HOEP and the lag of the HOEP for each specification. The results show that the null hypothesis of exogenous HOEP and exogenous lag of HOEP cannot be rejected in most cases. [57] This implies that empirical estimates

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[55] As noted by Melino and Peerbocus (2008) – between 80-85% of Ontario exports go to the New York market.

[56] There is also some evidence (significance at 10% level) that, for all industrial, iron and steel mills and ferro-alloy manufacturing, and motor vehicle manufacturing in 2005, and motor vehicle manufacturing in 2008, the validity of the instruments is questionable.

[57] To test whether the two instrumented regressors, ln(price) and ln(lag(price)), can be treated as exogenous regressors, a "difference-in-Hansen-Sargan" statistic is computed for each specification. A large statistic indicates strong evidence to reject the null hypothesis of that the instrumented regressors are exogenous. The

from IV are comparable to OLS results. Coefficient estimates of current prices with respect to motor vehicle manufacturing, iron and steel mills, petroleum and metal ore mining are either insignificant or possess a positive sign. On the other hand, an increase in the HOEP is in many cases, significantly correlated (at the 1%, 5%, 10% levels) with a reduction in demand by all industrials, the pulp and paper industry, and electric power generation. The coefficient estimates of current prices are comparable in magnitude to prior estimates and relatively consistent over time. Coefficient estimates of lagged electricity prices are positive and statistically significant (at the 1%-10% levels) ranging between 0.02 and 0.07 in value for all industrials, and from 0.09 to 0.43 for pulp and paper and electricity power generation, transmission, and distribution.

3.4.3 Sensitivity Analysis

Table 12 offers some further sensitivity analyses. So far we have not exploited the panel features of our data as we have run separate regressions for each year. The table contains estimates obtained from pooling together data across all years and employing year dummies in order to control for the potentially confounding effects of time specific shocks. As can be seen, we do not obtain very different results.

Table 13 redoes the analysis of Table 9 but with hourly data. Specifically, while the dependent variable (natural log of electricity demand) and the natural log of the contemporary wholesale electricity price are for each hour over the sample period, the lagged wholesale price is the natural logarithm of the average price over the previous 12 hour peak or off peak hour, depending on whether the dependent variable is price during an off peak or peak hour. Therefore, when the dependent variable is demand during a during peak hour (7 am to 6:59pm), the lagged price is the average hourly price from 12 am to 6:59 am (off-peak hours). Similarly, when demand is for an off peak hour (7 pm to 6:59pm), the lagged price is the hourly price from 7 am to 6:59pm (peak hours). However, our key findings remain unchanged. Empirical estimates are remarkably similar to those contained in Table 9.

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test results show that, except for all industrials in 2006 and 2008 and electric power generation, transmission and distribution in 2005, the null hypothesis cannot be rejected in most specifications. A discussion of using Sargan-Hansen statistics to test for exogeneity of instrumented regressors can be found in Hayashi (2000), pp. 232-234.

Finally, Table 14 compares the own price elasticities and the cross price elasticities with results from the previous chapter. Price Elasticities from Chapter 2 are computed based on the following formulas and evaluated at the mean peak-hours HOEP and mean off-peak-hours HOEP:

$$\varepsilon_{ij} = \frac{(1/2)d_{ij}\left(P_j/P_i\right)^{1/2}}{a_i}, \qquad i, j = \text{o, p and } i \neq j, \tag{11}$$

and

$$\varepsilon_{ii} = -\varepsilon_{ij}, \qquad i = \text{o, p}, \tag{12}$$

while the price elasticities from this chapters are based on results presented in Table 10. In general, the price elasticities from the linear log-log consumer theory based model are quite different from those from the GL cost function based model. The price elasticities from the consumer demand model tend to be larger in magnitude than the GL model's ones. Also, own price elasticities and cross price elasticities in the consumer demand model are allowed to be positive and negative. This is probably due to the fact that (1) the consumer demand model is a partial equilibrium model where a firm is not limited two only two choices, and (2) Z does not succeed in controlling for all income shocks. In contrast, the GL model explicitly constraints the number of choices available to a firm to just two. Further, the price elasticities from the consumer demand model are restricted to be constant over prices and demand levels in our log-log specification, while the GL model allows variation of price elasticities over prices. A different choice of prices could possible bring the estimates of the GL model closer to those of the consumer demand model.

3.4.4 Conclusion

There is relatively limited published research on demand elasticities by industrials and the effect of aggregate demand of industrials on electricity by prices. This paper attempts to fill this gap by employing data for summer months from 2005-2008 for the province of Ontario. The use of data over multiple years enables us to assess the sensitivity of our findings to year specific shocks. Data obtained on special request from the IESO allows us to evaluate the effects of price on consumption across different industries.

We obtain remarkably consistent findings across different estimation methodologies. Most industries – with the exception of motor vehicle manufacturing and petroleum and coal products manufacturing – respond in varying degrees to contemporaneous changes in price. What is even more robust are the effects of lagged prices. An increase in lagged prices is significantly associated with higher current consumption – offering evidence that industrials do shift consumption across time in order to exploit the benefits of lower prices during off peak hours. Our results offer support to the notion that policies which encourage efficient demand management by industrials will result in positive spillovers to all consumers.

Chapter 4

Market Shares, Sales, and Local Competition in Retail Gasoline Markets: Evidence from Station Level Data[58]

4.1 Introduction

What is the marginal impact of an additional outlet on the distribution of station specific market shares and sales? Are such effects conditional on whether the outlet belongs to a vertically integrated refiner or independent retailer? Does the brand affiliation of the outlet matter? Alternatively, do outlets belonging to the same firm compete similarly as outlets belonging to different firms? Does another outlet result in cannibalization or the creation of new demand?

There is much research on the effects of local sellers on retail gasoline prices. However, the effects of competition on station specific market shares have been relatively ignored. This is especially true when one focuses on differences between within brand and between brand competition as well as the relative impacts of vertically integrated refiners and independents. This is unfortunate, given that the above questions address key concepts regarding firm strategy and competitive dynamics within a retail industry. Resolving these ambiguities is also important from the perspective of competition policy.

We attempt to contribute to the literature by exploiting a unique micro data set of gasoline stations for the cities of Calgary, Saskatoon, Regina, Winnipeg, and Toronto. The data consists of pooled single day (in a given month) observations with respect to the universe of gasoline outlets in each city over time. Specifically, we possess data on station specific sales and posted prices based on a single day observation for each month from January 2007 to March 2007 for Toronto and for a three month period from the end of 2006 to the beginning of 2007 for the other cities. The novelty of these data arises from the availability of: (1) information on the brand affiliation and physical characteristics of each of these stations; and (2) data on station specific sales of regular grade gasoline that enable us to construct market shares.

The objective of our research is to evaluate the effects of the number of local competitors on the market share and sales of each retail outlet. Using the address of each outlet, we are able to calculate

[58] This chapter is based on joint work with Anindya Sen and Dennis Lu.

the number of competitors according to specific radii. This is important, as it captures travel costs to individual drivers, and is therefore, an accurate representation of the effects of local competition. The use of panel data at the station level over time and across cities allows us to mitigate the possibility of confounded estimates of the number of local competitors, through fixed effects that control for time invariant unobserved shocks that are jurisdiction specific or common to all stations at a point in time. Perhaps more importantly, the ability to match each outlet to its corresponding brand affiliation allows us to account for unobserved heterogeneity at the firm level, which could be an important determinant of pricing and competitive strategy. We are also able to test the sensitivity of our findings through the use of station fixed effects.

Under reasonable assumptions, more competitors in a local area should result in a decline in market share among incumbents, which is unlikely to be offset by the creation of new demand (from entrants).[59] Therefore, an increase in the number of competitors will be correlated with the cannibalization of market shares, and therefore, a business-stealing effect. While this is to be expected, we still think that some idea of empirical magnitudes is relevant given the paucity of research. The more important contribution of our research is through our efforts at assessing whether local competition is impacted by differences in strategies employed by vertically integrated refiners relative to independent retailers and if the effects of the number of outlets are conditional on brand affiliation. In other words, is competition less intense if an outlet only competes with other outlets affiliated with the same firm?

Our empirical estimates suggest that an additional station is significantly correlated with a decline in station specific market share. Perhaps of more importance, we find that the marginal impact of another outlet belonging to the same brand is somewhat larger in magnitude than the corresponding effect of a station affiliated with other brands. Similarly, we find that an additional same brand competitor is associated with a drop in station sales. Further, station specific market shares increase with distance to the nearest competitor, especially for same brand competitors. Intra-brand

[59] Assume that two incumbent firms each have 50% of a market consisting of a 100 units. A new firm enters with a slightly different product and does not take any market share from the incumbents but generates new demand of 20 units. For the incumbents' market shares to remain constant they would have to attract all of this new demand and split it evenly (so that each incumbent now has 60 out of 120 units). This is quite unlikely, and each incumbent probably attract some portion of the new demand. As a result while their overall sales will increase, their market shares will dip. We are very grateful to a colleague for pointing this out.

competition is also important with respect to prices, as an additional station affiliated with the same firm is correlated with a statistically significant drop in retail prices. However, the magnitude of this effect is quite small.

These findings are robust to the use (alternatively) of firm and station fixed effects, as well as an array of covariates intended at capturing station specific characteristics and local market concentration. The significant effects of same brand competition on station market share and sales along with modest price effects - suggest that the welfare effects of a marginal competitor might be reduced surplus, as entry potentially results in 'business-stealing' even among outlets affiliated with the same parent company.

While these results are consistent with standard text book Cournot models of spatial competition with travel costs, they also fit the predictions of other models. For example, aggressive intra-brand competition could also be the result of consumer preference for a specific brand because of customer loyalty programs. Alternatively, vertically integrated firms have an incentive to encourage competition between affiliated stations if it results in competitive pricing and higher joint profits (for the parent firm). The important implication is that measuring competition exclusively through the number of all local stations without taking into account brand affiliation - may yield misleading results on the true magnitude of competitive intensity. This result is aligned with recent studies (such as Lewis (2008)) which establish the importance of seller type and the composition of competition with respect to price effects.

The remainder of this paper is structured as follows. Section 4.2 discusses the literature. The data are described in Section 4.3. Section 4.4 presents the empirical specifications, and Section 4.5 summarizes the main empirical findings. Section 4.6 concludes.

4.2 Literature Review

How does competition affect retail market shares? Broadly speaking, most theory is based on Hotelling (1929)-type monopolistic competition models where product differentiation occurs through outlet location. As articulated by Netz and Taylor (2002), the market share effect suggests that firms' have an incentive to locate close to each other or *minimally differentiate* in order to capture more customers. On the other hand, given that this will result in greater price competition and reduced margins, firms also have an incentive to locate further away from competing rivals in order to *maximally differentiate*. This is known as the market power effect. A firm's decision on location and hence on whether it should minimally or maximally differentiate, depends critically on assumptions regarding the distribution of consumers, product homogeneity and elasticity, and transport costs. The important point of course, is that location impacts firm specific market shares. [60]

We are unaware of many papers that have assessed empirically, the effects of the number local gasoline outlets on station specific market shares. Sen and Townley (2010) study the effects of outlet density on city specific market concentration and average outlet sales. Netz and Taylor (2002) and Pinkse and Slade (1998) focus on the determinants of geographical clustering of gasoline stations rather than on the effects of clustering on station specific market shares.[61] They then make inferences on the existence of ‘market share’ or ‘market power’ behaviour by retail stations. This is probably due to the unavailability of station specific market shares from their data. In comparison, the availability of market share information in our sample enables us to directly evaluate the relative magnitudes of the ‘market power’ and ‘market share’ effects. The data also allows us to assess the effects of local sellers by firm type (vertically integrated refiner, independent retailer) as well as by brand affiliation.

In summary, there is extremely limited research on the effects of number of local sellers on outlet specific market shares and sales. This is unfortunate as the results of such analysis could plausibly shed more light on the welfare effects of an increase in local sellers. For example, if an increase in sellers results in lower prices, than consumers are better off because they obtain more surplus. However, these welfare effects might be attenuated if the increase in stations essentially results in more overhead costs and the cannibalization of existing market shares with no increase in demand. This would occur if entrants are basically ‘stealing market share’ from incumbents and not attracting new business.

4.3 Data

Our data were obtained from Kent Marketing, a private firm in London, Ontario, that collects this information from the universe of outlets in each market that it surveys, resulting in a sample of 1,053

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[60] Please see Eaton (1972), Eaton and Lipsey (1975), and d’Aspremont, Gabszewicz, and Thisse (1979) for further details.

[61] Pinkse and Slade (2002) look at all stations owned by vertically integrated firms in Vancouver, while Netz and Taylor (2002) use data on all stations in the Los Angeles Basin Area.

stations.[62] Kent Marketing collects data on prices, sales volumes and other station specific attributes or characteristics through on-site visits to each retail outlet.[63] The data also contains the complete postal address of each outlet along with the latitude and longitude of its location. The identity of the affiliated firm – whether vertically integrated or independent – is also available. Unfortunately, details of the exact contractual affiliation between the dealer and the affiliated firm are not collected by Kent Marketing.

Table 15 offers some more details on the division of retail outlets among the vertically integrated firms. Esso, Petro-Canada, and Shell are the national level vertically integrated firms with outlets across the country. Co-op and Husky are regional vertically integrated refiners in Western Canada. The division of stations is pretty even among national vertically integrated firms (from 15% to 17%) and regionals (roughly 9%) in Calgary. Esso is clearly the dominant firm (23% of stations) in Regina and Saskatoon. On the other hand, Shell has approximately 25% of all outlets in Winnipeg. Esso also has the largest market share of stations (nearly 27%) in Toronto. Collectively, independent retailers possess more than 30% of all stations in Calgary, Regina, and Saskatoon.

4.4 Empirical Strategy

We use the following base empirical specification in order to evaluate the effects of local competition on station specific market shares and sales;

$$MS_{ijt} \text{ or } \ln SALES_{ijt} = \beta_0 + \beta_1 NCOMP_{ijt} + \beta_2 CRUDE_t + \beta_3 CRUDE(-1)_t + \beta_4 SSPUMP_{ijt} + \beta_5 LCSTOR_{ijt} + \beta_6 MCSTOR_{ijt} + \beta_7 SCSTOR_{ijt} + \beta_8 CWASH_{ijt} + \beta_9 DHWAY_{ijt} + \beta_{10} POP_{jt} + \beta_{11} HHINC_{jt} + \beta_{12} UNEMP_{jt} + \beta_{13} DWORK_{jt} + \sum FFE_i \text{ (or } NVI_i) + \sum DFE_i + \sum CFE_j + \sum MFE_t + \varepsilon_{ijt} \quad (13)$$

[62] As detailed in table 1, there are roughly 288 outlets in Calgary, 72 outlets in Saskatoon, 71 outlets in Regina, 200 outlets in Winnipeg, and slightly less than 700 outlets in Toronto.

[63] There are currently over 8,000 outlets surveyed by Kent Marketing across Canada. Data on sales volumes are collected through pump meter readings during on-site visits. Further details are available at http://www.kentmarketing.on.ca/markets.html.

Here, *i* refers to the station, *j* the city and *t* to the specific day the data were recorded, and ε_{ijt} is the (independently and identically distributed) error term. Summary statistics of all variables used in the analysis are shown in Table 16.

MS_{ijt} ($SALES_{ijt}$) is the market share (sales of regular grade gasoline) of station *i* in city *j* at day *t* and recorded when the particular outlet was surveyed, constructed from its sales of regular grade gasoline and relative to all other stations in a 3 km radius.[64] The choice of 3 km is based on recent studies (e.g., Barron, Taylor, and Umbeck) (2004) and Lewis (2008)) that use a 1.5 mile radius to define local competition among gasoline outlets.[65] While this is our primary measure of competition, we also assess the sensitivity of our estimates by using $NCOMP_{ijt}$, which is the number of other retail outlets either within station i's Forward Sorting Area (FSA) or within a distance of 3 km. The FSA refers to the first three digits of a station's six digit postal code. Calculating the number of competitors by FSA was straightforward given the availability of postal code data. Corresponding information on the latitude and longitude of each station along with geo-coding software was used to construct the number of other outlets within a 3 km radius.

Sample statistics (from Table 16) reveal that the mean number of stations within 3 km (with respect to each station in our data) to be slightly above seven. On average, each station possesses 14% of regular grade market share (within 3 km). Figure 4 gives the distribution of observations by number of stations. Most stations (roughly 40%) compete with 5-8 other competitors in a 3 km radius. Figure 5 shows a 3 km circle drawn around a random outlet in Toronto with the location of other competitors.

There are, of course, other factors that impact retail prices independent of local competition. Cost shocks are captured through crude oil prices. $CRUDE_t$ is the day specific crude oil price corresponding to the day that information on station i's retail price was collected. Par Edmonton prices are used for cities in Manitoba and westward, while Brent Montreal crude oil prices are employed for Toronto. $CRUDE(-1)_t$ is the average crude oil price in the previous month.

Station specific characteristics may be important for product differentiation and for explaining a particular station's market share. To account for that we employ $SCSTOR_{ijt}$, $MCSTOR_{ijt}$, and

[64] After deleting stations with missing data, we are left with a sample of 794 outlets.

[65] Our results do not change if we use a 4 km radius. However, the marginal effects of a local competitor unsurprisingly start to diminish once we use a radius equal to or exceeding 6 km.

$LCSTOR_{ijt}$, which are dummy variables that denote whether the station has a small, medium, or large convenience store, respectively. The dimensions for small, medium, and large stores are 1 – 50 sq. feet, 50 – 200 sq. feet, and greater than 200 sq. feet. The omitted category is an outlet with no convenience store. $CWASH_{ijt}$ is a 1-0 indicator for the presence of a car wash. Finally, $SSPUMP_{ijt}$ is the number of self-service pumps. While the availability of a car wash and pumps might attract more business and market share, it may potentially force stations to charge higher prices because of an increase in marginal costs.

Station specific market shares may also be influenced by local economic factors, demographics and geography. $DHWAY_{ijt}$ represents distance (in km) to the nearest highway, which was calculated using google maps and www.mapquest.com.[66] Arguably, stations on or very near to a highway may enjoy some degree of market power and thus be able to charge higher prices. Finally, we employ census level variables (from the 2006 Census of Canada) to control for the effects of local characteristics. POP_{jt}, is total population, $HHINC_{jt}$ is average household income, $UNEMP_{jt}$ is the population unemployment rate, and $DWORK_{jt}$ is the percentage of drivers in the FSA that commute to work.[67]

Finally, we employ fixed effects to account for any unobserved factors that might impact retail market shares. $\sum DFE_i$ represents day of week fixed effects capturing the day of collection, $\sum FFE_i$ are firm fixed effects (for each vertically integrated firm), $\sum CFE_j$ are city specific fixed effects, and $\sum MFE_t$ are month fixed dummies. Hence, the impacts of local competition are identified by exploiting time-series variation (albeit for a short period) within cities, holding constant time invariant firm and city specific differences. The use of firm fixed effects is particularly important to account for unobserved firm specific heterogeneity that might affect outlet strategy regarding competition and prices. Alternatively, we use NVI_i which denotes whether the outlet is affiliated with

[66] An outlet's proximity to a highway was determined through google maps. The driving distance was then calculated through www.mapquest.com.

[67] The radius around a station does not correspond to census tracts. Therefore, we used the following method to assign values of census based variables to each circle around an outlet. Suppose the 3 km circle intersects 3 census tracts, where the whole of tract #1, half of tract #2 and one third of tract #3 lies within the circle. The population of the circle is then 100% of population of #1 + 50% of population of #2 + 33.33% of population of #3.

a national and regional vertically integrated firm. The omitted category is then an independent retailer.

The above specification imposes the constraint that the marginal effect of another station is invariant across firm type and brand. We also use simple difference-in-difference specifications to evaluate whether the effects of local sellers are conditional on firm type or brand. Specifically, we create covariates that (separately) measure the number of stations affiliated with vertically integrated firms and independent retailers within a 3 km radius. These variables are then interacted with NVI_i, which captures whether the effects of competition by firm type (vertically integrated or independent) are conditional on the affiliation of the outlet (with a vertically integrated or independent firm). We also investigate the importance of brand affiliation. This is accomplished by creating variables that separately identify the number of same brand sellers in a 3 km radius from outlets owned by other vertically integrated refiners and independents. Further details are available from the next section.

4.5 Empirical Results

4.5.1 Baseline Results

Table 17 contains our baseline OLS estimates. Column 1 consists of estimates of the effects of local outlets measured by FSA. Columns 2 and 3 contain results of the effects of local sellers within 3 km. The difference between columns 2 and 3 is that column 3 also contains firm specific dummies for each national and regional vertically integrated firm. On the other hand, the differential effects of vertically integrated firms (relative to independent retailers) in columns 1 and 2 are captured through two dummies that represent national and regional vertically integrated firms. Unless stated otherwise, standard errors of coefficient estimates are clustered by brand in order to account for unobserved correlations between outlets belonging to the same firm.[68]

[68] In other words the standard errors are clustered by the same parent firm. We present our results from levels models. However, we did not obtain any different results from comparable log-log specifications. Given the small number of clusters, we use the method proposed by Cameron, Gelbach, and Miller (2008) to adjust the standard errors. We obtained similar standard errors by clustering on city and month. Standard Wooldridge tests of first order autocorrelation could not be rejected. Therefore, we checked our results by also using Generalized Least Squares (GLS) that explicitly correct for first order autocorrelation. These estimates were virtually identical to OLS estimates with clustered standard errors.

Empirical results in Table 17 clearly demonstrate the importance of employing competition measures based on radii. Specifically, while the competition variables in all columns are negative and statistically significant (at the 1% level), the coefficient estimate of the number of competitors based on the FSA, is larger in magnitude – possibly because of the presence of other local unobserved characteristics.[69] Corresponding results from columns 2 and 3 suggest that one more competitor (in a 3 km radius) is significantly correlated with a 2.29 percentage point drop in the market share of an individual outlet. Given these findings, the rest of the paper is focused on the effects of competitors within a 3 km radius.

In terms of other covariates, one more self-service pump is significantly correlated (at the 1% level) with a 0.27 percentage point increase in station market share (columns 2 and 3). Further, being a national vertically integrated firm is significantly associated (at the 1% level) with 3.8 percentage point rise in station market share (column 2).

4.5.2 Instrumental Variable Estimation

OLS and fixed effects (FE) coefficient estimates might plausibly be biased by omitted variables or simultaneity bias. We think that this is relevant given the heterogeneity in outlet location. Unobserved factors might certainly be correlated with location. This is true whether we consider location across or within cities. Specifically, a firm's decision to locate an outlet in a particular neighborhood or city is based on a variety of factors ranging from existing household income and the purchasing power of consumers, trends in demographics, and business growth potential. All these factors impact the future profitability of an outlet. An inability to properly account for such unobserved determinants of outlet location will result in confounded estimates of the effects of local competition.

Given the short time duration of the data, using city fixed effects and census sub division covariates should reduce the magnitude of measurement error by purging coefficient estimates of the number of local sellers of bias from correlations with unobserved neighbourhood and city specific factors that are fixed over time. However, this is certainly not a sufficient strategy. An alternative approach would be through instruments that could plausibly explain the incidence of outlets with and across neighbourhoods and cities.

[69] This should not be surprising as one can imagine outlets that are within 3 km of each other but are also in different forward sorting areas.

A possible instrument may be the number of local businesses. On the one hand, studies by geographers suggest that interdependencies between retail industries result in clustering within areas.[70] Further, an increase in local businesses may reasonably signal enhanced growth opportunities and therefore, offer firms an incentive to establish more retail gasoline outlets. Another rationale is that zoning regulations may require gas stations to be located in business areas, farther away from residential areas. Therefore, there should be a positive correlation between the number of businesses and the number of gas stations. On the other hand, the number of businesses should not be correlated with station-specific market share once the number of gas stations and the market size (as proxied by population size and local economic characteristics) are controlled for. In order to test this hypothesis, we collected data on the number of local businesses by FSA from Canada Post's website. We also downloaded information on the number of residences as another instrument. The number of residences should be negatively correlated with the number of gas stations due to zoning restrictions. First and second stage Instrumental Variables (IV) estimates are detailed in Table 18.

First stage regressions (in column 1) reveal that consistent with the above intuition, the coefficient estimate of the number of businesses is positive and statistically significant (at the 1% level). On the other hand, while the number of local residences is also significant (at the 1% level), it possesses a negative sign. A potential explanation might be that gasoline outlets prefer to locate in areas with a clustering of retail industries rather than household consumers. What is important is the statistical significance of both our instruments as second stage estimates would otherwise be confounded (Bound, Baker, and Jaeger (1995), Staiger and Stock (1997)).[71] Employing a standard test of overidentifying restrictions, we are also unable to reject the null hypothesis of instrument exogeneity.[72] This implies that there is no evidence to suggest that the instruments are correlated with the error term. Both the results of both tests suggest that both the number of businesses and the number of residences are valid instruments. The coefficient estimate of the number of local competitors (from the second stage equation in column 2) is negative and comparable in magnitude relative to OLS estimates in table 4 and is statistically significant at the 1% level.

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[70] For example please see Mushinski and Weiler (2002).

[71] A joint test of significance for the two instruments yields a Chi-squared statistic= 15.32 and *P*-value = 0.0005.

[72] We regressed the residuals from the IV regressions on all exogenous variables and obtained an uncentered R^2 = 0.000006608. Therefore, the test statistic n x R^2 = 0.02198 with a *P*-value = 0.8821.

In summary, we place limited emphasis on these findings as we are unable to conduct any sensitivity analysis because of the unavailability of alternate instruments. The only results that we note are that the coefficient estimate of the number of local sellers is comparable in magnitude to OLS results – but remains negative and statistically precise. Therefore, the remainder of this study is based on OLS and FE estimates.

4.5.3 Competition by Firm

The previous estimates do not distinguish the effects of local competition by firm type. Broadly speaking, this might be accomplished by taking into account the firm affiliation of each competing outlet or whether the outlet is affiliated with a vertically integrated refiner or independent retailer. Column 1 in Table 19 consists of an interaction between the local competitors (all stations within a 3 km radius to station *i*) and a dummy for whether the station in question (station *i*) is affiliated with a vertically integrated firm. Column 2 also consists of a similar interaction, with the difference between columns stemming from the use of a vertically integrated firm dummy (to identify station *i*) in column 1, and separate firm dummies (for all vertically integrated firms) in column 2.

In contrast, columns 3 and 4 decompose the number of local competitors covariate according to whether these local sellers are affiliated with a vertically integrated firm or an independent. These competition variables are then interacted with dummies that distinguish whether 'station *i*' is affiliated with a national or regional vertically integrated refiner. As is the case in columns 1 and 2, the objective of the interaction is to assess whether different types of firms have varying competitive effects, which are in turn, are conditional on station *i*'s affiliation. Column 3 contains a dummy to distinguish whether 'station *i*' is with a vertically integrated firm, while column 4 instead contains separate firm specific dummies for each vertically integrated firm.

Column 5 investigates the marginal impacts of local competitors by brand. Specifically, we distinguish between local competitors belonging to the same brand and the number of vertically integrated and regional refiners and independents by brand. Column 6 uses the same covariates but also adds dummies for each firm, while column 5 relies on a dummy if the station in question is affiliated with a vertically integrated firm.[73]

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[73] Unlike columns 1-4, we do not run nor report the interaction of these competition covariates with brand dummies. This is because preliminary regressions reveal them to be statistically insignificant.

Empirical estimates in column 1 imply that one more local competitor is, on average, significantly associated with a 2.46 (-1.65 + (-0.81)) percentage point drop in the market share of a station affiliated with a vertically integrated firm– a relationship that is statistically significant at the 1% level. Analogously, an additional competitor is correlated with a 1.65 percentage point decline in the market share of a station affiliated with an independent. Estimates in column 2 are very similar.

Results contained in columns 3 and 4 reveal some interesting refinements to the above findings. Specifically, the effects of an additional outlet are conditional not only on the affiliation of the station in question but also with respect to the composition of local competitors (within a 3 km radius). On average, an additional outlet affiliated with a vertically integrated firm is roughly correlated with a 1.6 percentage point drop in the market share of a local station. However, the identity of the outlet is important, as one more vertically integrated (independent) outlet is associated with a further 0.96 (statistically significant at the 1% level) decline in the average market share of a station affiliated with a vertically integrated firm – resulting in a marginal effect of 2.56 (1.6+0.96). All these results are significant at either the 1% or 5% levels. On average, one more independent retailer in a 3 km radius is roughly associated with a 2 percentage point drop in the market share of an outlet (vertically integrated or independent).

Intriguingly, results from columns 5 and 6 demonstrate that a same brand competitor (coefficient estimate of -2.6 or -2.75) belonging to a vertically integrated firm, has a slightly larger effect on station specific market shares relative to other vertically integrated competitors from different brands (coefficient estimate of -2.3 or -2.21) as well as in comparison to independents from other brands (coefficient estimate of -2.03 and -2.08). Further, all these coefficient estimates are statistically significant at the 1% or 5% levels.

These results are interesting. Conventional wisdom would suggest that an increase in the number of same brand outlets within a local area might in fact result in a lessening of competition, as tacit collusion would arguably be easier. In other words, transactions costs to coordination should be lower if most outlets in a 3 km radius are affiliated with the same parent firm. Our results, in fact, suggest the opposite. On average, controlling for a variety of station specific and market characteristics, an increase in same brand outlets is significantly correlated with a larger decline in station market share relative to a rise in outlets belonging to different brands.

Table 20 contains estimates of the effects of local competition on the natural logarithm of outlet specific sales of regular grade gasoline and is organized similarly to table 4. Empirical estimates of the effects of all competitors (columns 1 and 2) and competition defined by vertical integration (columns 3 and 4) are statistically insignificant. However, corresponding estimates of the impact of same brand sellers (columns 5 and 6) are statistically significant (at the 1% level) and suggest that a 1% increase in the mean number of competitors in a 3 km radius is correlated with roughly a 0.007% -0.009% drop in outlet specific sales of regular grade gasoline. This may seem to be a small effect. However, a 1% increase in competition is roughly equivalent to 0.01 competitors as the mean of the number of competitors is 1.16. Therefore, one could say that an additional same brand competitor is associated with a 0.7%-0.9% drop in outlet sales.

4.5.4 Price Regressions

We also possess data on the price charged by each station for regular grade gasoline for the day in which its sales were recorded. Given the high frequency in price changes to retail gasoline, more time-series variation would be desirable. However, estimating the effects of the number of local competitors is definitely a worthwhile exercise given the limited number of studies that have been able to exploit variation in prices across stations for multiple cities. At the very least, it is useful sensitivity analysis in order to evaluate our findings with respect to station specific market shares.[74,75]

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[74] In terms of station specific data, the classic references are Shepard (1991) and Slade (1992). Barron et al. (2004) employ data on prices charged on a single day (in 1997) by every gasoline station in Phoenix, Tucson, San Diego and San Francisco. Hastings (2004) exploits station level data from the Los Angeles and San Diego metropolitan areas. The data contains a price observation for each station in February, June, October, and December of 1997. Hosken, McMillan, and Taylor (2008) study the effects of the number of local sellers through a three-year panel of weekly prices for 272 stations in the Virginia suburbs of Washington (D.C.). Atkinson, Eckert, and West (2009) use station level data on retail prices collected every 2 hours (8:00 a.m. to 10:00 p.m.) over a roughly 3 month time period (August – November) in 2005, for 27 of the 28 stations in Guelph (Ontario). Lewis (2008) uses posted price data for 327 stations in the San Diego area recorded on each Monday morning for 2000-01. Iyer and Seetharaman (2003; 2008) employ station level data from St. Louis and study the effects of competitive intensity and local demographics on product and pricing choices.

[75] Other studies have used station level data from Canada but focus on the existence of retail price cycles rather than on the effects of the number of local sellers. These include Eckert (2002; 2003), Eckert and West (2004a; 2004b), Noel (2007a; 2007b; 2009), and Lewis and Noel (2011). The mainly cross-city variation in prices in our data does not allow us to evaluate the existence of Edgeworth price cycles. Houde (2012) investigates the effects of commuting patterns on spatial differentiation using station level data (between 1991 and 2006) from Quebec. Carranza, Clark, and Houde (2011) use station level data from twin cities in Ontario and Quebec to

Table 21 is organized similarly to Table 19 and Table 20, with exception being the dependent variable, which is the retail price (excluding all taxes) of regular grade gasoline. Empirical estimates from columns 1 and 2 do not offer any evidence that the number of stations affiliated with vertically integrated firms have different competitive effects relative to independent retailers. This is because the coefficient estimates of the number of local stations as well as its interactions with the vertically integrated dummy are all statistically insignificant. Further, estimates of the number vertically integrated and independent retailer stations (columns 3 and 4) along with associated interaction are also statistically insignificant. Broadly speaking, these results indicate that competitive effects of outlets are not conditional on affiliation with a vertically integrated or independent retailer.

On the other hand – consistent with the marginal effects of same brand stations on market shares and sales - estimates from columns 5 and 6 suggest that, on average, an increase in the number of outlets with the same brand affiliation – irrespective of whether the brand is a vertically integrated firm or independent retailer - is significantly correlated (at the 1% level) with a 0.15 cents per liter drop in station specific prices. An increase in the number of outlets affiliated with *different* regional vertically integrated refiners is correlated (at the 1% level) with 0.03 cents per liter reduction in prices. In contrast, one more independent retailer is associated with a 0.06 cents per liter rise in station specific prices. We obtain extremely similar results employing firm fixed effects (column 6). However, it is important to note that the marginal effect of a station – even if it does belong to the same brand – is still quite modest.

4.5.5 Sensitivity Analysis

Table 22 contains the results of some further robustness tests that focus on the effects of competition on outlet specific market shares and prices.[76] Columns 1, 2, and 3 include: (1) city specific average current and one week lagged wholesale prices (downloaded from www.mjervin.com) as well as day specific and average crude oil prices in the previous month; and (2) a Herfindahl Hirschman Index (HHI) calculated through firm specific market shares based on all outlets within a 3 km radius.[77] To

study the effects of price floor regulations on local competition, prices, and productivity. Erutku and Hildebrand (2010) employ price data averaged across stations in Quebec.

[76] For the sake of brevity, we do not report sensitivity tests with respect to sales as they are similar to results obtained with respect to market shares. They are available on request.

[77] This index is a common measure of market concentration or power and is the sum squared of individual firm market shares.

be clear, the firm specific affiliation of all outlets within a 3 km radius around each station i were taken into account to calculate the sales and therefore, market share accruing to each firm through its outlets. The objective is to evaluate whether the effects of outlets are conditional on local market concentration. The dependent variable in column 1 is the station specific gas price, and market share of each individual outlet in columns 2 and 3. Local competition is measured as the number of all other competitors in columns 1 and 2, but separately as the number of same brand and other brand stations in column 3. Columns 4, 5, and 6 are organized similarly - but study the consequences of employing station specific fixed effects aimed at controlling for unobserved heterogeneity at the outlet level. As a result, other station specific covariates had to be omitted as right hand side covariates (in columns 4, 5, and 6).[78]

Coefficient estimates of the HHI are statistically significant in columns 2 and 3 (with respect to station market share). Relative to earlier estimates, coefficient estimates of the number of local competitors are slightly smaller in magnitude in columns 1 and 2. However, they remain statistically significant (at either the 1% or 10% levels of significance). On the other hand, the estimate of the marginal effect of another same brand competitor (in column 3) is larger in magnitude and statistically significant at the 1% level. Specifically, the result implies that an additional same brand competitor is significantly associated (at the 1% level) with a 3 percentage point in the market share of station 'i' – controlling for the number of other stations affiliated with vertically integrated refiners and independent retailers. Further, results contained in columns 4-6 demonstrate that these findings remain robust to the use of station fixed effects. Therefore, results on the impacts of local sellers from previous tables should not be attenuated by unobserved heterogeneity that is station specific and fixed over time.[79]

4.5.6 Distance and Market Share

Our findings so far suggest a statistically significant and negative correlation between local competition and station specific market share, with particularly strong effects stemming from same

[78] Another option would have been to use random effects for each station. However, using a Hausman test we rejected the null hypothesis that Fixed Effects and Random Effects coefficients are not different systematically.

[79] We conducted some further sensitivity analysis by measuring the number of same brand competitors through dummy variables; specifically, through separate dummies for 1, 2, 3, and 4 or more competitors in a 3 km radius. As expected, our findings did not change, as the marginal effects of additional stations increase with the number of outlets. We do not report these estimates for the sake of brevity, but they are available on request.

brand competitors. If this is true, then all else being held constant, the market share of an individual station should rise as the distance between outlets increase. In order to evaluate this, we calculated the distance between each station *i* and its closest competitor, and used it as a covariate. We also interacted this covariate with a dummy denoting whether the nearest competitor is a same brand outlet. The relevant estimates are contained in Table 23, with the differences in columns stemming from the use of the number of local competitors within 3 km radius, a dummy variable indicating whether the station is affiliated with a vertically integrated firm, or alternatively, firm fixed effects. The dependent variable across all columns is the market share of the individual station.

Our findings are remarkably robust across columns. A 1 km increase in the distance between stations is significantly correlated (at the 1% level) with between a 7-9 percentage point increase in the market share of station *i*. Perhaps of greater interest is the statistically significant coefficient estimate (at the 5% level) of the same brand dummy indicating a further 4 percentage point rise in the market share of the station. Further, the coefficient estimate of the number of local competitors remains statistically significant (at the 1% level) and comparable to previous estimates. In summary, these results offer further evidence on how close proximity among same brand competitors can result in cannibalization.

4.6 Conclusion

We attempt to contribute to the literature by employing a unique panel dataset on station specific market shares and sales. The data contains information on regular grade sales of each retail gasoline outlet across five Canadian cities. The opportunity to examine retail outlet market shares for all outlets – even for a single city is extremely rare. Our study focuses on the effects of local sellers, in an attempt to understand the impact of an additional station. We exploit the rich details available from the data in order to evaluate whether the effects of local sellers are conditional on firm type and brand. This exercise is of merit given the considerable gap with respect to the empirical effects of retail outlets by firm and brand affiliation.

Unsurprisingly, we find evidence of a correlation between more stations and reduced market share. Perhaps more importantly, a same brand outlet has a larger effect on station specific market share and sales compared to the corresponding impacts of outlets affiliated with other brands. This result is robust to the use of station specific covariates as well as station and firm specific fixed effects intended to account for unobserved heterogeneity. We also find that more distance between outlets is correlated with an increase in station specific market share. These findings suggest that an additional local competitor does not create new demand and results in a cannibalization of market share among existing outlets. Other studies (Barron et al. (2000), Hastings (2004), Lewis (2008)) have examined the effects of brand affiliation on station prices. To the best of our knowledge, we are unaware of any other research that has examined the effects of brand affiliation on station market share.

While we place limited emphasis on our price regressions, the modest impacts of additional same brand sellers along with the above findings on effects on market share, do suggest that entry by retail outlets may not be welfare enhancing. This, of course, is a standard conclusion of Cournot models of competition which treat entry as endogenous. In other words, free-entry will always result in more than a socially efficient number of competitors as the marginal entrant's contribution in terms of generating more surplus (through new customers) will be outweighed by the sunk costs of entry, as the entrant will have an incentive to 'steal' customers from neighboring firms.

However, there are reasons as to why these results might also be indicative of efficient behavior. Eckert and West (2005) report reductions in the number of company owned outlets, lessee dealers and branded independents, but an increase in the number of commission dealer operated stations that occurred in Toronto from the mid 1990s to the early 2000s. It is possible that an increase in commission dealer operated stations at the expense of company operated outlets resulted in reduced alignment of an outlet's incentives with overall firm profitability. As a consequence, firms have an incentive to devise unobserved reward schemes based on outlet comparisons within a confined geographical area in order to eliminate moral hazard and double marginalization. This could potentially explain the significant effects of same brand competition, which we observe in our data.

In a similar vein, a vertically integrated firm would benefit from the implementation of policies that encourage vigorous competition among affiliated outlets, and that results in prices closer to marginal costs. Consequently, joint retail profits to the vertically integrated firm would be higher, as retail outlets with market power would otherwise set prices at an inefficiently high level (from the perspective of the vertically integrated firm).[80]

The above discussion assumes supply side based explanations for our findings. However, the importance of brand affiliation may merely reflect strong consumer preferences. While retail gasoline

[80] This is again, a standard text book result. For more detailed models that incorporate price as well as non-price competition, please refer to Winter (1993).

is a homogenous good, the introduction of customer loyalty and reward programs – such as points accumulation through credit cards that capture the amount of purchase at specific outlets – may introduce significant product differentiation, brand preference among consumers, as well as switching costs – which is consistent with Borenstein (1991). Therefore, the relevant yardstick of competition for an outlet is not necessarily the number of all other retail stations in a geographical area, but the number of other outlets affiliated with the same parent firm. To summarize, more research is needed to understand the differential effects of same brand outlets as well as possible correlations with specific contractual affiliation with parent firms. We intend to pursue these with more structural methods of estimation. However, given the relative dearth of relevant literature, we think that the reduced form estimates in this paper to be of interest – especially given their robustness.

Chapter 5
Conclusion

The three papers in this thesis examine the impact of competitive pricing or competition on market participants. The first two papers concentrate on the response of industrial customers to the real time pricing in the wholesale electricity market in Ontario, whereas the last paper centers on the effect of local competition on local market shares and sales of gas stations. It is hoped that results from these three studies could provide valuable policy lessons to public policy makers in their task to create or maintain competition in different energy markets, so as to improve efficiencies in the markets. The scope of each paper is narrow but focused, dealing with one particular aspect of competition in each market as it is recognized that large-scale market reform is often political infeasible, and a small step is more practical and can help to gain momentum.

In the electricity sector in Ontario, competitive wholesale market exists alongside regulated retail market. While the inability to allow retail prices to reflect changes in wholesale price shocks certainly causes market distortions and inefficiencies, the ability to manipulate the incentives to industrials and their impact on wholesale prices can be of key policy importance. In spite of the absence of data on non-RTP scheme participant to eliminate possible self-selection bias in the analysis, both the first two papers provide modest evidence that industrial customers who are directly connected to the transmission grid do shift consumption from peak to off-peak hours in order to exploit the benefits of lower prices during those times. Also, lower market demand by industrial customers due to higher peak hour prices is significantly associated with a decline in the HOEP. The marginal impact of an increase in demand due to lower off-peak prices is however of a much smaller magnitude. Furthermore, coefficient estimates of the effects of demand by industrial customers are larger in magnitude than corresponding estimates for other customers.

Together, these results offer support to the notion that policies that encourage efficient demand management by industrial customers will result in considerable savings in generation, transmission and distribution costs and positive spillovers to all customers. On such policy is a better alignment of the pricing of network transmission charges (for industrial customers) with real time market usage. The current pricing structure in Ontario offers limited benefits to customers who shift loads across peak and off-peak periods. By charging higher rates during peak hours, we should expect similar benefits as offered by RTP in the wholesale market.

As the current study focuses mainly on the short run elasticities, an immediate extension of this study is to model long run elasticities using models such as partial adjustment model, error-correction model and/or autoregressive distributed lag model. This should complement the short run results and give us a better picture of the dynamics of RTP on demand over time.

Furthermore, the study of Ontario's wholesale market can serve as a starting point for future research in a comparative study between Ontario's and Alberta's approach to deregulation of their electricity sector. Especially, given Alberta's deregulatory reform is more complete, with much fewer interventions in the generation side of business, it would give further insights into the functioning of RTP under different sets of supply side constraints.

Also, another natural extension from this study is to investigate the responsive of small business and residential customers to the time-of-use pricing. With the introduction of smart meters to almost every household and small business in Ontario, most of these customers are paying time-of-use prices. Smart meters allow hydro companies to collect data on how much electricity these customers are using and when they are using it. These detailed data should allow better modeling of the consumption patterns of small business and residential customers under time-of-use pricing, and allow a more detailed study of the interaction between the HOEP, the industrial demand, and the commercial and residential demand than what has been done in Chapter 2 of this thesis.

As regards retail gasoline markets, at the core of concerns of public policy makers is one of maintaining competition. The third paper presents results of one aspect of such competition – local competition and its effects on the business of individual gasoline stations. It is important to public policy makers because given free-entry, the number of competitors tends not to be socially efficient as the marginal entrant's contribution in terms of generating more surplus through new demand will often be outweighed by the sunk costs of entry, as the entrant will also have an incentive to 'steal' customers from neighboring firms. The third paper finds evidence of a correlation between more stations, as well as distance from the nearest competitor, and reduced market share (and sales). More interestingly, it is found that the effect of one additional same brand local competitor on the market share and sales of an existing gas station tends to be larger than that of an additional local competitor of a different brand.

These results could be evidence of a cannibalization of market share among existing stations, but, could also be indicative of efficient behavior. Specifically, given the increasing share of commission dealer operated stations and reduced alignment of objectives between individual stations and the parent firm, the parent firm may use intra-brand outlet competition within a confined geographical area as a mean to eliminate moral hazard and double marginalization. Also, the observed brand affiliation effect could also be explained by production differentiation, strong consumer preferences and switching costs due to the introduction of various loyalty and reward schemes by the oil companies.

Due to the absence of relevant data in the present data set, a detailed analysis of these alternative explanations could not be carried out. The findings of the third paper however could provide a basis for future research into a better understanding of the effects of specific contractual affiliation between individual stations and parent firms on the business performance of individual stations and their implications on efficiency.

Furthermore, our findings are conditional on the same branded competitors already existing in the local market. But what makes a firm choose to locate two of its outlets close to each other. More generally, it is of interest to examine outlet location choice, as characterized by the spatial distribution of outlets. Do outlets stay away from each other to maintain market power? Or do they stay close to each other to capture market shares? Do firms create within brand competition by locating their own outlets close to each other? Or is the clustering of same brand outlets just a response to between brand competition? The answers to these questions should us help to address key concepts such as firm strategy and competitive dynamics within the retail gasoline market.

Appendix A
Figures and Tables

Figure 1: Supply and Demand in the Wholesale Electricity Market

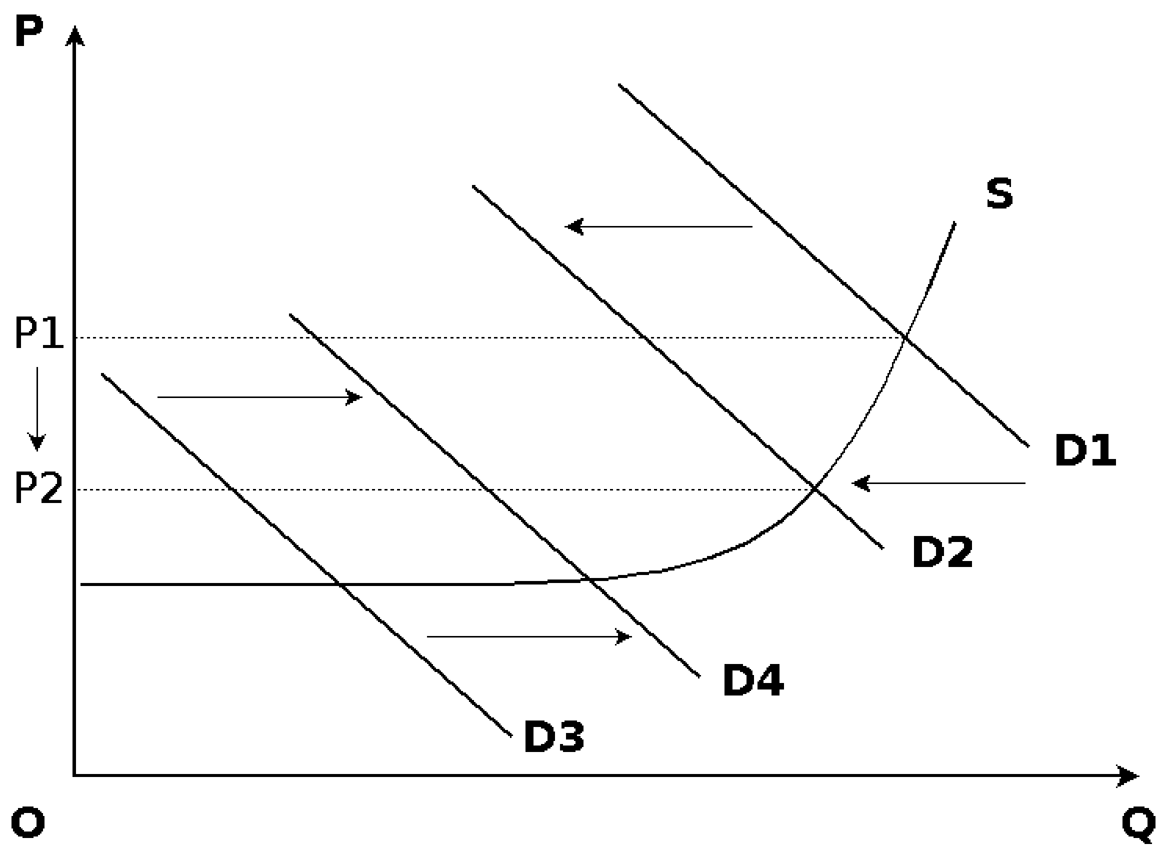
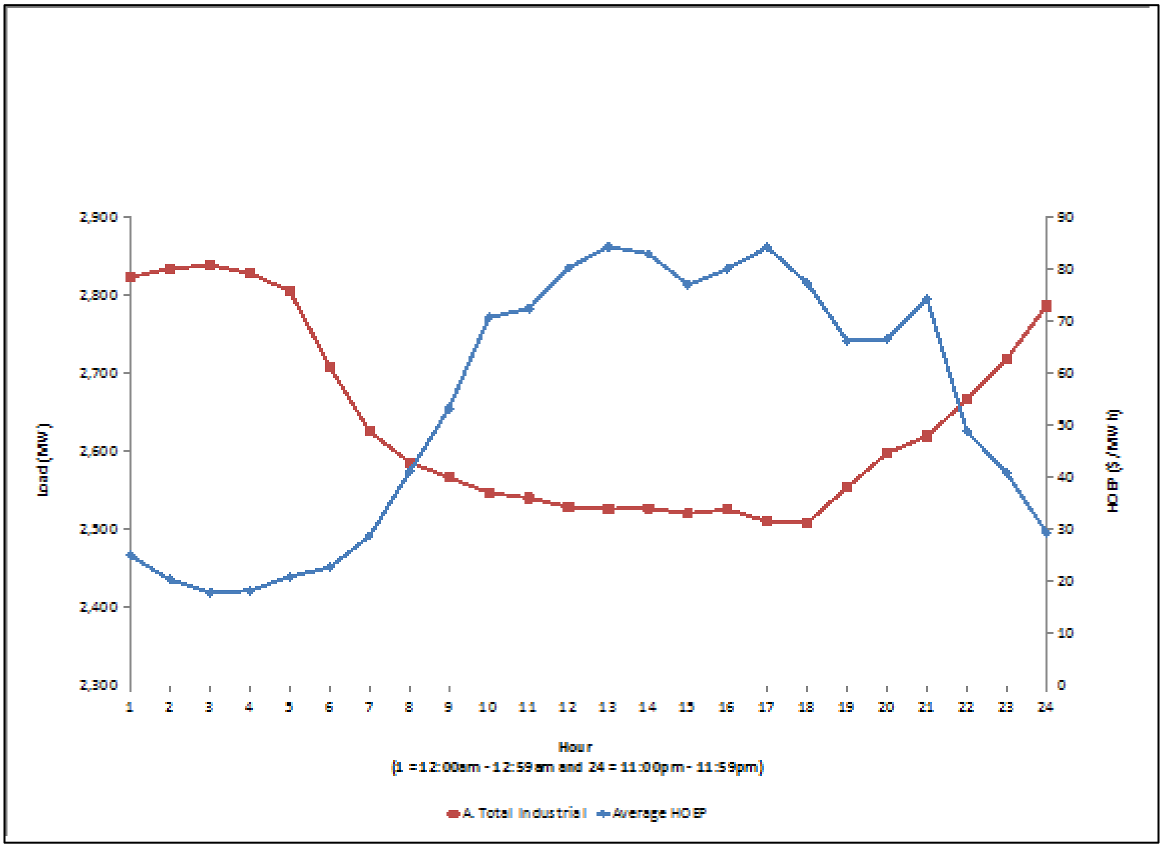


Figure 2: Average Hourly Demand - Total Industrial (Summer 2008)



Source: Electricity Price data (in Canadian dollars) obtained from the website of the Independent Electricity Supply Operator (IESO) (http://www.ieso.ca/imoweb/siteShared/whoweare.asp). Industrial load data obtained on special request from the IESO.

Figure 3: Average Hourly Demand by Industry (Summer 2008)

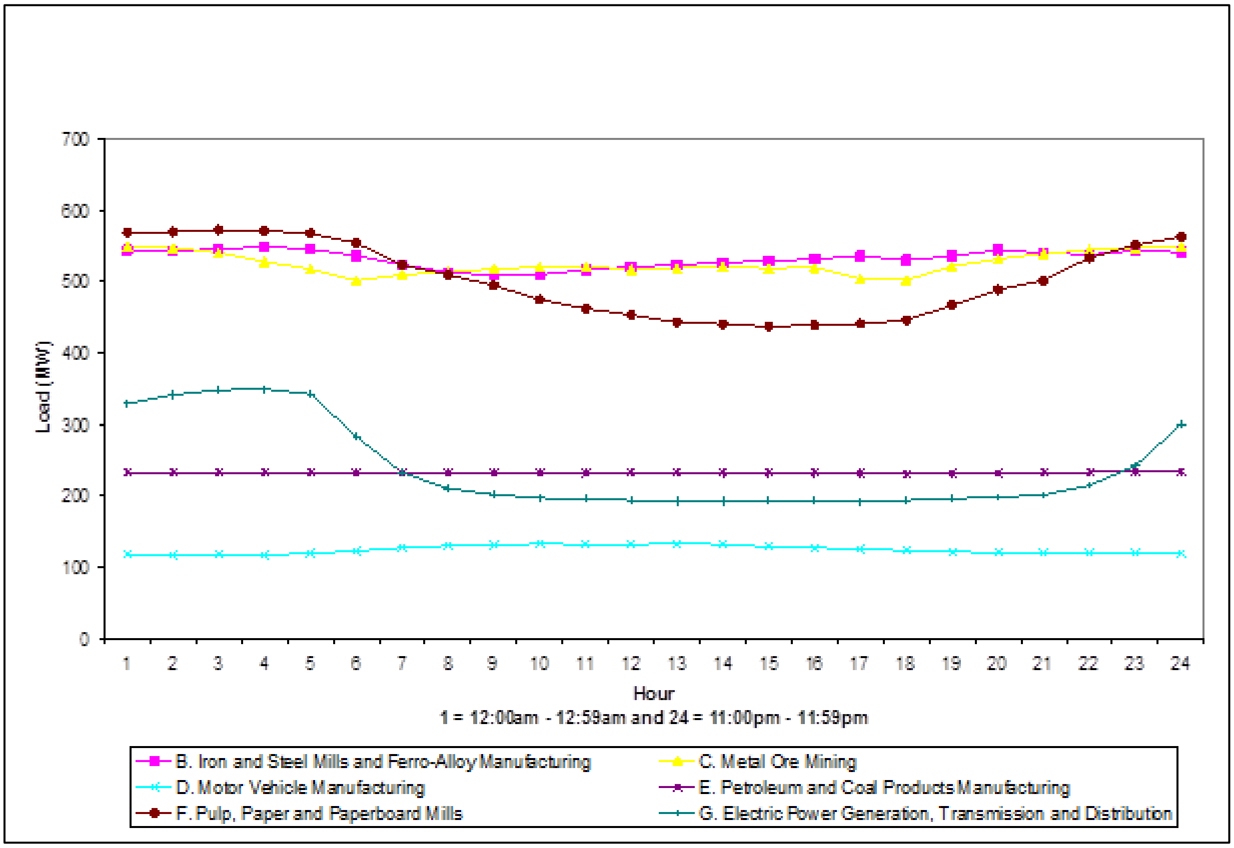


Figure 4: Distribution of Data Points by Number of Local Sellers

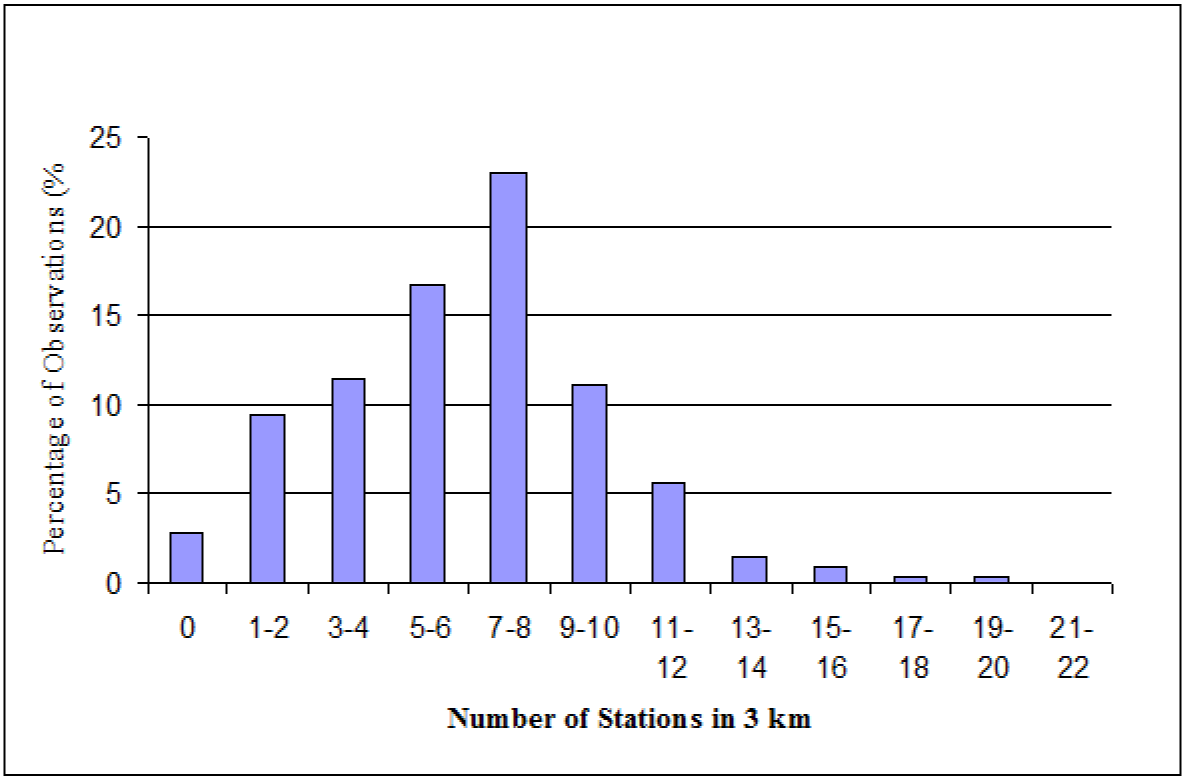


Figure 5: Three-kilometer Radius Around a Gasoline Station in Toronto

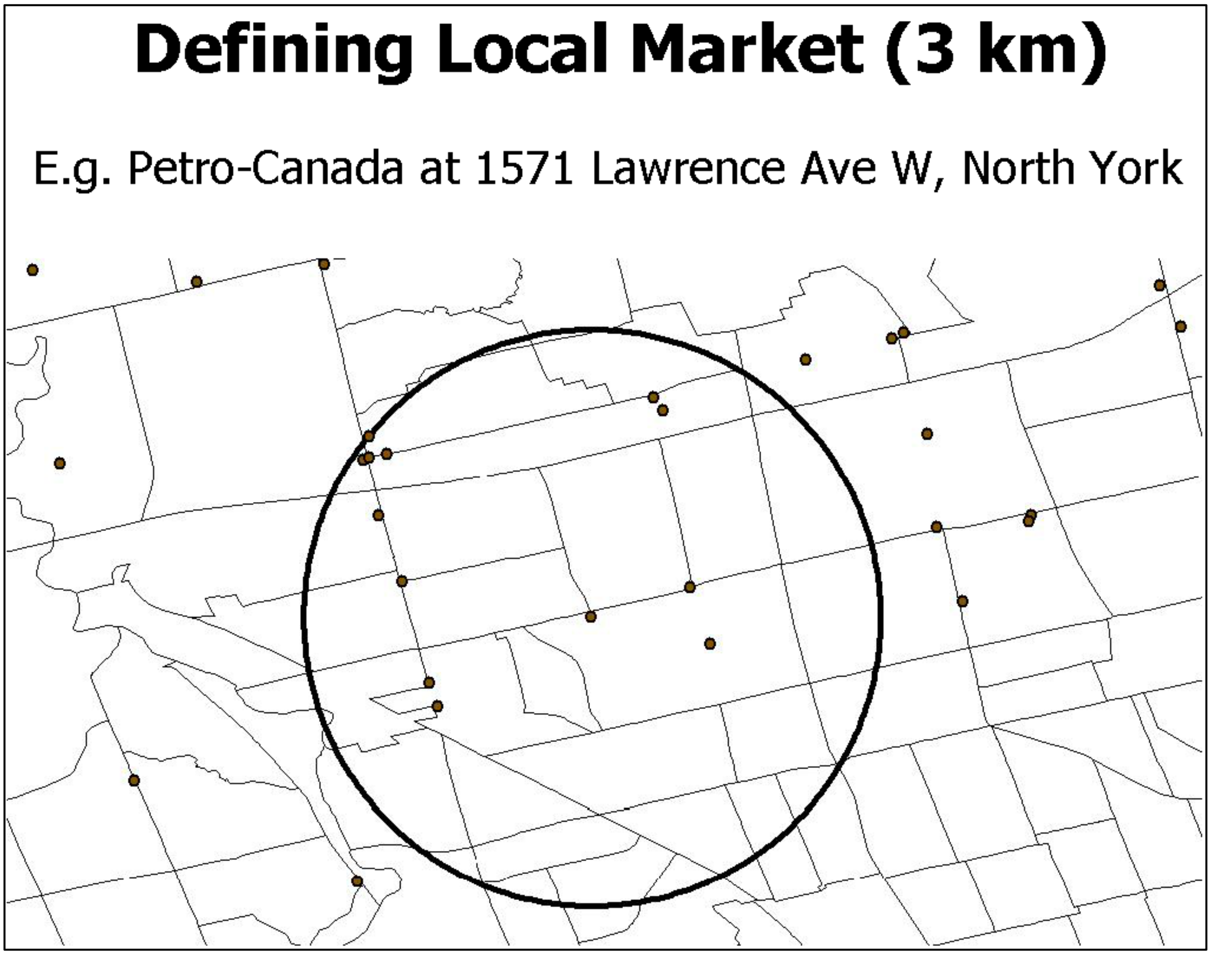


Table 1: Literature Review of RTP Studies

Herriges et al. (1993)	Investigate the efficacy of an RTP program (with respect to 46 customers) introduced by the Niagara Mohawk Corporation in New York State	Using CES model they obtain elasticities of substitution from (roughly) 0.08 to 0.13
Patrick and Wolak (2001)	Estimate the real time price effects on demand for electricity from the England and Wales (E&W) electricity market based on customer level data from large and medium-sized industrial and commercial customers (1991 -1995)	Results from Generalized McFadden (GM) cost functions suggest significant within-day inter-temporal cross price elasticities with considerable industry heterogeneity
Schwarz et al. (2002)	Estimate demand elasticities employing (June–September from 1994 to 1999) data from 110 large customers of the Duke Power Corporation	CES models yield obtain intra-day elasticities in the range of 0.11.
Boisvert et al. (2004)	Data from 43 industrial and commercial customers that volunteered to participate in Central and Southwest Service's RTP programs between 1998 and 2001 in Oklahama.	Employing Generalized Leontief (GL) models, they find elasticities of substitution from 0.10 to 0.18.
Taylor, Schwarz, and Cochell (2005)	Use hourly customer data (from 1994 to 2001) based on the Duke Hourly Energy Program during the summer months of June, July, August, and September.	Focusing on intra-day hourly data, their results (from a GM specification) suggest electricity consumption to be complementary during adjacent hours but substitutable between hours that are further apart. However, they do not calculate elasticities between peak and off-peak hours.
Boisvert et al (2007)	Evaluate the effects of a RTP type scheme (to consumers through hourly pricing and load data from 119 large customers of Niagara Mohawk from 2000 to 2004.	Results from a Generalized Leontief (GL) model suggest that RTP pricing results in load shifting by large consumers as estimates reveal an elasticity of substitution of 0.11.

Table 2: Electricity Demand (in MW/hr) by Industry

	Summer of 2005	Summer of 2006	Summer of 2007	Summer of 2008
A. Total industrial	6,385,711	6,152,129	5,593,258	5,822,908
As % of A				
B. Iron and steel mills and ferro-alloy manufacturing	17.24%	19.03%	18.27%	20.18%
C. Metal ore mining	17.69%	17.57%	20.13%	19.90%
D. Motor vehicle manufacturing	6.18%	6.50%	5.88%	4.73%
E. Petroleum and coal products manufacturing	7.01%	7.65%	8.55%	8.82%
F. Pulp, paper, and paperboard mills	23.70%	21.56%	17.72%	19.07%
G. Electric power generation, transmission, and distribution	8.91%	8.95%	10.26%	9.06%
Ontario demand	41,626,431	39,702,447	38,988,305	37,891,802
Industrial demand as % of Ontario demand	15.34%	15.50%	14.35%	15.37%

Source: Data obtained on special request from the website of the Independent Electricity Supply Operator (IESO).

Table 3: Summary Statistics for Chapter 2

A. Summary Statistics of Variables Used in Industry Demand Regressions
(Summer Months, Daily Data, P = Peak Hours; O = Off Peak Hours)

Years = 2005-2008						
Demand Variables		**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Total Industrial (MW/hr)	P	368	2600.54	173.13	2161.17	3019.42
	O	368	2823.98	183.73	2356.75	3257.42
Iron and Steel Mills and Ferro-	P	368	497.13	56.39	299.67	616.50
Alloy Manufacturing (MW/hr)	O	368	514.79	55.35	381.50	647.50
Metal Ore Mining (MW/hr)	P	368	499.43	55.43	276.08	588.17
	O	368	519.09	54.14	300.92	605.92
Motor Vehicle Manufacturing	P	368	162.46	56.84	59.83	252.25
(MW/hr)	O	368	153.93	52.29	58.25	241.17
Petroleum and Coal Products	P	368	215.92	35.84	133.75	259.17
Manufacturing (MW/hr)	O	368	216.45	36.29	136.17	260.92
Pulp, Paper and Paperboard Mills	P	368	511.78	105.97	301.83	801.08
(MW/hr)	O	368	607.31	100.15	381.92	832.92
Electric Power Generation,	P	368	203.72	29.38	155.92	293.17
Transmission and Distribution	O	368	299.39	34.58	217.17	409.33
(MW/hr)						
Other Variables						
HOEP ($/MWh)	P	368	72.79	31.71	24.99	234.61
	O	367	41.06	16.75	4.84	123.95
Toronto Temperature (°C)		368	21.6	3.46	9.35	31.10

(Table 3 continues)

(Table 3 continued)

B. Summary Statistics of Variables Used in Price Regressions
(Summer Months, Hourly Data)

Years = 2005-2007

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Electricity Price ($/MWh)	6624	58.01	38.46	2.41	533.17
HHI	6624	5389.05	302.36	4549	6294
Ontario Demand (MW/hr)	6624	18163.83	3114.61	11699	27005
Exports (MW/hr)	6624	1277.51	613.61	0	3298
Imports (MW/hr)	6624	940.93	583.86	0	4028
Coal (MW/hr)	6624	3616.58	1132.34	292	5659
Gas (MW/hr)	6624	1261.33	683.61	449	3542
Nuclear (MW/hr)	6624	9646.35	683.31	5670	11180
Hydro (MW/hr)	6624	3383.54	969.44	1369	5744
CAD-USD Exchange Rate	6624	1.13	0.07	1.04	1.26
Weekend Dummy	6624	0.28	0.45	0	1
Holiday Dummy	6624	0.02	0.15	0	1
Day	6624	15.84	8.85	1	31

Table 4: Generalized Leontief (GL) Estimates

	(1)	(2)	(3)	(4)
Industry	**2005**	**2006**	**2007**	**2008**
Total industrials				
d_{po}	0.011**	0.032*	0.026	0.017**
	(0.004)	(0.017)	(0.022)	(0.009)
Iron and Steel Mills and Ferro-Alloy Manufacturing				
d_{po}	0.011	0.026	0.027	0.004
	(0.015)	(0.018)	(0.025)	(0.012)
Metal Ore Mining				
d_{po}	0.000	0.0413*	0.026	0.007
	(0.006)	(0.018)	(0.017)	(0.009)
Motor Vehicle Manufacturing				
d_{po}	0.020	0.039	0.012	0.000
	(0.016)	(0.028)	(0.020)	(0.020)
Petroleum and coal products manufacturing				
d_{po}	0.0002	0.034**	0.036*	0.021**
	(0.005)	(0.017)	(0.019)	(0.007)
Pulp, paper, and paperboard mills				
d_{po}	0.0355**	0.046*	0.002	0.023*
	(0.013)	(0.025)	(0.03)	(0.012)
Electric power generation, transmission, and distribution				
d_{po}	0.0113	0.0004	0.048	0.043*
	(0.016)	(0.044)	(0.044)	(0.022)
N	92	92	92	90

Notes: The dependent variables are industry specific log (peak demand /off-peak demand). Robust standard errors are in parentheses, where * p<0.05, ** p<0.01, *** p<0.001. An AR(1) correction was added to the models. For each year, the seven industrials were estimated together using nonlinear seemingly unrelated regressions developed by Gallant (1975). Daily mean temperature and month dummies and day of week dummies were included in all regressions. Peak hours are from 7:00am to 6:59pm of each day. The data are daily for June, July, and August. Two 2008 observations were dropped due to negative off-peak HOEP.

Table 5: Elasticities of Substitution between Peak and Off-Peak Hours

Industry	Estimate		Bootstrap_SE	95% CI_Lower	95% CI_Upper
Total industrials					
2005	0.0232	*	0.0113	0.0027	0.0319
2006	0.0659	*	0.0343	0.0166	0.0882
2007	0.0540	*	0.0308	0.0123	0.0804
2008	0.0359	*	0.0175	0.0127	0.0554
Iron and steel mills and ferro-alloy manufacturing					
2005	0.0229		0.0272	0	0.0745
2006	0.0531		0.0349	0	0.0946
2007	0.0559		0.0435	0	0.1141
2008	0.0080		0.0216	0	0.0482
Metal Ore Mining					
2005	0		0.0148	0	0.0042
2006	0.0852		0.0332	0	0.1198
2007	0.0545	*	0.0250	0.0072	0.0796
2008	0.0149		0.0179	0	0.0313
Motor Vehicle Manufacturing					
2005	0.0416		0.0286	0	0.0851
2006	0.0825		0.0535	0	0.1612
2007	0.0264		0.0445	0	0.0835
2008	0		0.0278	0	0.0326
Petroleum and coal products manufacturing					
2005	0.0004		0.0137	0	0.0197
2006	0.0692	*	0.0324	0.0056	0.1328
2007	0.0734	*	0.0281	0.0103	0.1043
2008	0.0455	*	0.0149	0.0180	0.0594

(Table 5 continues)

(Table 5 continued)

Industry	Estimate		Bootstrap_SE	95% CI_Lower	95% CI_Upper
Pulp, paper, and paperboard mills					
2005	0.0731	*	0.0276	0.0188	0.1273
2006	0.0966	*	0.0494	0.0114	0.1712
2007	0		0.0472	0	0.1221
2008	0.0516		0.0305	0	0.1071
Electric power generation, transmission, and distribution					
2005	0.0231		0.0298	0	0.0736
2006	0		0.0771	0	0.0930
2007	0.1020		0.0747	0	0.2839
2008	0.0892	*	0.0445	0	0.1683

Notes: * = significant at 5% level based on bias corrected confidence intervals. Standard errors were estimated using a recursive design wild bootstrap method developed by Goncalves and Kilian (2004). Peak hours are from 7:00am to 6:59pm of each day. The data are daily for June, July, and August.

Table 6: Ordinary Least Squares (OLS) and Instrumental Variable (IV) Estiamtes with respect to Hourly Ontario Electricity Price (Dependent Variable) during Peak Hours

	2005		2006		2007	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**
Ontario Industrial Demand	0.021	0.054 **	0.048 ***	0.047 ***	0.022 *	0.032 **
	(0.020)	(0.024)	(0.011)	(0.014)	(0.013)	(0.16)
Other Industrial, Commercial,	0.017 ***	0.020 ***	0.028 ***	0.028 ***	0.016 ***	0.017 ***
& Residential Demand	(0.006)	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)
Exports	0.013 *	0.018 **	0.026 ***	0.026 ***	0.014 ***	0.015 ***
	(0.008)	(0.009)	(0.005)	(0.005)	(0.005)	(0.005)
Imports	0.001	-0.001	-0.018 ***	-0.018 ***	-0.015 ***	-0.016 ***
	(0.008)	(0.008)	(0.005)	(0.005)	(0.005)	(0.006)
Coal	-0.012 *	-0.013 *	-0.023 ***	-0.022 ***	-0.004	-0.006
	(0.007)	(0.008)	(0.005)	(0.005)	(0.005)	(0.006)
Gas	0.010	0.007	-0.006	-0.006	0.0009	0.0002
	(0.008)	(0.008)	(0.006)	(0.006)	(0.005)	(0.006)
Nuclear	-0.014	-0.018 **	-0.030 ***	-0.029 ***	-0.017 ***	-0.017 ***
	(0.009)	(0.009)	(0.005)	(0.005)	(0.006)	(0.006)
Hydro	0.013	0.010	-0.017 ***	-0.017 ***	0.002	0.001
	(0.011)	(0.011)	(0.006)	(0.006)	(0.006)	(0.006)
Herfindahl Hirschman Index	-0.017	-0.024 **	-0.0004	-0.0003	-0.036 ***	-0.035 ***
	(0.017)	(0.025)	(0.006)	(0.006)	(0.007)	(0.007)
Exchange Rate	375	225	189	194	-2.71	-19.8
	(295)	(298)	(158)	(161)	(129)	(130)
Weekend	31.2 ***	32.0 ***	19.2 ***	19.2 ***	28.9 ***	28.1 ***
	(8.98)	(9.08)	(4.35)	(4.39)	(3.99)	(3.96)
Holiday	12.9	14.9	23.4 *	23.2 *	25.8 ***	24.4 ***
	(11.3)	(11.6)	(12.6)	(12.5)	(5.47)	(5.44)
Day	0.438	0.202	-0.097	-0.092	0.021	0.005
	(0.382)	(0.399)	(0.136)	(0.144)	(0.119)	(0.119)
Intercept	-565	-425	-321 **	-323	72.4	63.3
	(399)	(401)	(148)	(148)	(155)	(154)
N	1104	1104	1104	1104	1104	1104
Adjusted R2	0.477	0.486	0.676	0.6833	0.523	0.5336

(Table 6 continues)

(Table 6 continued)

	2005		2006		2007	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**
Test of Relevancy: H_0: Excluded Instruments Jointly Zero						
F-statistic		639 ***		486 ***		277 ***
Test of Overidentifying Restrictions: H_0: Excluded Instruments Exogenous						
Score Chi2		7.07 ***		2.29		12.4 ***

Notes: Peak hours are defined as 7 am to 6:59pm. The data are hour specific. Ordinary Least Squares (OLS) estimates are presented with Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors with Bartlett kernel and bandwidth=24. IV estimation uses Lag 2 of Ontario Industrial Demand and Toronto's Temperature as Instruments for Ontario Industrial Demand and are presented with HAC standard errors with Bartlett kernel and bandwidth=24. Standard errors are in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month and hour dummies are included in this model but not reported.

Table 7: OLS and IV Estimates During Off Peak Hours

	2005		2006		2007	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**
Ontario Industrial Demand	0.0009	0.009	0.026 ***	0.028 ***	0.008	0.013
	(0.007)	(0.014)	(0.006)	(0.009)	(0.006)	(0.009)
Other Industrial, Commercial,	0.011 ***	0.012 ***	0.021 ***	0.022 ***	0.003	0.004
& Residential Demand	(0.004)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
Exports	0.007 *	0.009 *	0.019 ***	0.020 ***	0.003	0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Imports	-0.008	-0.009	-0.015 ***	-0.015 ***	0.002	0.001
	(0.005)	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)
Coal	-0.008 **	-0.009 **	-0.016 ***	-0.016 ***	0.002	0.002
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Gas	0.017 **	0.016 **	0.002	0.001	0.015 ***	0.015 ***
	(0.007)	(0.008)	(0.006)	(0.006)	(0.004)	(0.005)
Nuclear	-0.018 ***	-0.020 ***	-0.020 ***	-0.021 ***	-0.002	-0.003
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Hydro	-0.006	-0.007	-0.020 ***	-0.020 ***	0.0002	-0.0000
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Herfindahl Hirschman Index	0.010	0.008	0.005	0.005	0.0002	0.001
	(0.007)	(0.007)	(0.003)	(0.003)	(0.003)	(0.003)
Exchange Rate	303 **	274 **	89.6	84.2	40.5	26.7
	(133)	(138)	(70.7)	(74.5)	(67.8)	(70.0)
Weekend	10.2 ***	11.1 ***	11.2 ***	11.2 ***	8.30 ***	8.40 ***
	(2.96)	(3.29)	(2.20)	(2.24)	(1.43)	(1.42)
Holiday	8.05	9.19	5.89 **	5.97 **	9.05 ***	8.98 ***
	(5.73)	(6.09)	(2.74)	(2.78)	(1.60)	(1.59)
Day	0.452 **	0.395 **	-0.144	-0.148	0.156 ***	0.173 ***
	(0.195)	(0.202)	(0.096)	(0.099)	(0.056)	(0.056)
Intercept	-350 **	-325	-165 ***	-162 **	-86.5	-90.2
	(165)	(167)	(63.2)	(64.1)	(76.8)	(76.3)
N	1104	1104	1104	1104	1104	1104
Adjusted R2	0.679	0.686	0. 752	0.7579	0.748	0.753

(Table 7 continues)

(Table 7 continued)

	2005		2006		2007	
	OLS	**IV**	**OLS**	**IV**	**OLS**	**IV**
Test of Relevancy: H_0: Excluded Instruments Jointly Zero						
F-statistic		344 ***		230 ***		152 ***
Test of Overidentifying Restrictions: H_0: Excluded Instruments Exogenous						
Score Chi2		4.13 **		3.18 *		2.17

Notes: Off peak hours are defined as 7 pm to 6:59 am. The data are hour specific. Ordinary Least Squares (OLS) estimates are presented with Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors with Bartlett kernel and bandwidth=24. IV estimation uses Lag 2 of Ontario Industrial Demand and Toronto's Temperature as Instruments for Ontario Industrial Demand and is presented with HAC standard errors with Bartlett kernel and bandwidth=24. Standard errors are in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month and hour dummies are included in this model but not reported.

Table 8: Summary Statistics for Chapter 3

Summary Statistics of Variables Used in Industry Demand Regressions					
Years = 2005-2008					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Total Industrial	736	2712.26	210.53	2161.17	3257.42
Iron and Steel Mills and Ferro-Alloy Manufacturing	736	505.96	56.53	299.67	647.50
Metal Ore Mining	736	509.26	55.63	276.08	605.92
Motor Vehicle Manufacturing	736	158.20	54.74	58.25	252.25
Petroleum and Coal Products Manufacturing	736	216.19	36.04	133.75	260.92
Pulp, Paper and Paperboard Mills	736	559.54	113.58	301.83	832.92
Electric Power Generation, Transmission and Distribution	736	251.56	57.61	155.92	409.33
HOEP	736	56.87	29.97	-1.96	234.61
Ont's Monthly Unemployment Rate	736	6.90	0.47	5.80	7.40
CAD-USD Exchange Rate	736	1.11	0.08	0.99	1.26
Holiday Dummy	736	0.02	0.15	0	1
Weekend Dummy	736	0.29	0.45	0	1
Toronto’s Cooling Degree Days	736	0.73	1.61	0.00	9.64
NYC minus Toronto’s Cooling Degree Days	736	0.62	1.80	-7.42	8.82

Table 9: Ordinary Least Squares (OLS) Estimates by Industry Using Month Dummies

A. Total Industrial								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.06491	***	-0.0748	***	-0.0578	***	-0.0492	***
	(0.0068)		(0.0068)		(0.0107)		(0.0036)	
lag(ln(price))	0.0671	***	0.0940	***	0.0637	***	0.0351	***
	(0.0067)		(0.0101)		(0.0068)		(0.0039)	
Intercept	7.9986	***	7.8518	***	7.8069	***	7.9276	***
	(0.0527)		(0.0566)		(0.0561)		(0.0236)	
N	184		184		184		182	
Adj R^2	0.5874		0.6221		0.5416		0.5030	
B. Iron and Steel Mills and Ferro-Alloy Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0299	**	-0.0102		-0.0386	**	-0.0299	***
	(0.0146)		(0.0186)		(0.0197)		(0.0077)	
lag(ln(price))	0.0225		0.0649	***	0.0143		-0.0036	
	(0.0212)		(0.0143)		(0.0195)		(0.0085)	
Intercept	6.2342	***	5.9942	***	6.1583	***	6.4127	***
	(0.1535)		(0.1252)		(0.1476)		(0.0602)	
N	184		184		184		182	
Adj R^2	0.0636		0.3199		0.4144		0.2555	
C. Metal Ore Mining								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0626	***	0.0051		-0.0240	**	-0.0358	***
	(0.0115)		(0.0245)		(0.0107)		(0.0084)	
lag(ln(price))	0.0089		0.0931	***	0.0342	**	0.0021	
	(0.0105)		(0.0277)		(0.0143)		(0.0096)	
Intercept	6.5640	***	5.9167	***	6.2835	***	6.3828	***
	(0.0915)		(0.1986)		(0.1005)		(0.0687)	
N	184		184		184		182	
Adj R^2	0.5184		0.5096		0.493		0.1065	

(Table 9 continues)

(Table 9 continued)

D. Motor Vehicle Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.2128	***	0.3688	***	0.3158	***	0.2026	***
	(0.0484)		(0.0654)		(0.0601)		(0.0482)	
lag(ln(price))	0.1214	**	0.2320	***	0.1772	***	0.0939	**
	(0.0563)		(0.0649)		(0.0579)		(0.0374)	
Intercept	3.8422	***	2.9232	***	3.1325		3.6857	***
	(0.4494)		(0.4844)		(0.4545)		(0.3095)	
N	184		184		184		182	
Adj R^2	0.3708		0.4068		0.3344		0.1811	

E. Petroleum and Coal Products Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.0665	**	-0.0169		0.0174	***	-0.0131	***
	(0.0315)		(0.0230)		(0.0054)		(0.0050)	
lag(ln(price))	0.0713	**	-0.0169		0.0129		-0.0067	
	(0.0314)		(0.0232)		(0.081)		(0.0047)	
Intercept	4.8005	***	5.3026	***	4.9055	***	5.5819	***
	(0.2709)		(0.1819)		(0.0548)		(0.0348)	
N	184		184		184		182	
Adj R^2	0.2348		0.7992		0.9511		0.8182	

F. Pulp, Paper and Paperboard Mills								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.1523	***	-0.2466	***	-0.2229	***	-0.1198	***
	(0.0129)		(0.0143)		(0.0243)		(0.0118)	
lag(ln(price))	0.0879	***	0.1307	***	0.0979	***	0.0887	***
	(0.0144)		(0.0181)		(0.0185)		(0.0114)	
Intercept	6.8159	***	6.8397	***	6.6109	***	6.3342	***
	(0.1090)		(0.0971)		(0.0933)		(0.0583)	
N	184		184		184		182	
Adj R^2	0.5017		0.5891		0.5007		0.5023	

(Table 9 continues)

(Table 9 continued)

G. Electric Power Generation, Transmission and Distribution				
	2005	**2006**	**2007**	**2008**
ln(price)	-0.3404 ***	-0.4103 ***	-0.2912 ***	-0.2490 ***
	(0.0332)	(0.0286)	(0.0356)	(0.0129)
lag(ln(price))	0.3103 ***	0.3694 ***	0.209 ***	0.1707 ***
	(0.0344)	(0.0276)	(0.0183)	(0.0159)
Intercept	5.7344 ***	5.5439 ***	5.7440 ***	5.7238 ***
	(0.2567)	(0.1522)	(0.1542)	(0.0853)
N	184	184	184	182
Adj R^2	0.6661	0.6727	0.6708	0.6657

Notes: Peak hours are defined as 7 am to 6:59pm, while off peak hours are from 7 pm to 6:59 am the next day. The lag of ln(price) is ln(price in previous period). Specifically, when the dependent variable is demand during peak hours (7 am to 6:59pm), the previous period is 12 am to 6:59 am (off-peak hours). When demand is for off peak hours (7 pm to 6:59pm), the previous period is 7 am to 6:59pm (peak hours). Three observations are dropped in the year 2008 because average price in previous period is negative and hence log cannot be taken. Ordinary Least Squares (OLS) estimates are presented with Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors with Bartlett kernel and bandwidth=24. Standard errors in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month dummies are included in the model but not shown in the table.

Table 10: Ordinary Least Squares (OLS) Estimates by Industry – Not Using Month Dummies, But Other Covariates

A. Total Industrial								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0100		-0.0548	***	-0.0382	***	-0.0424	***
	(0.0155)		(0.0104)		(0.0086)		(0.0034)	
lag(ln(price))	0.0773	***	0.0964	***	0.0714	***	0.0364	***
	(0.0106)		(0.0137)		(0.0053)		(0.0045)	
ln(Ontario's unemployment	-0.4311		-0.2412	***	-0.2035	***	-0.1905	
rate)	(0.3229)		(0.0510)		(0.0737)		(0.1493)	
ln(CAD-USD exchange rate)	-1.8449	**	0.4116		1.59824	***	0.1184	
	(0.9243)		(0.9973)		(0.5067)		(0.2123)	
Holiday	0.0042		-0.0222	*	0.0573	***	0.0328	***
	(0.0359)		(0.0123)		(0.0104)		(0.0064)	
Weekend	0.0204	**	0.0173	***	0.0276	***	-0.0060	
	(0.0098)		(0.0066)		(0.0072)		(0.0054)	
Toronto’s cooling degree	-0.0143	***	-0.0074	***	-0.0064	***	-0.0087	***
days	(0.0039)		0.0017		0.0014		(0.0030)	
Intercept	8.9089	***	8.1828	***	8.0069	***	8.2675	
	(0.7376)		(0.0769)		(0.1568)		(0.2903)	
N	184		184		184		182	
Adj R^2	0.5362		0.6488		0.6521		0.5407	

B. Iron and Steel Mills and Ferro-Alloy Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0191		-0.0474	*	-0.0526	*	-0.0324	***
	(0.0210)		(0.0245)		(0.0274)		(0.0072)	
lag(ln(price))	0.0230		0.0410	*	0.0065		-0.0019	
	(0.0190)		(0.0210)		(0.0242)		(0.0077)	
ln(Ontario's unemployment	-0.1371		-0.2838	**	-0.8928	***	-1.1548	***
rate)	(0.3935)		(0.1300)		(0.2936)		(0.3923)	

(Table 10 continues)

(Table 10 continued)-0.0065

B. Iron and Steel Mills and Ferro-Alloy Manufacturing				
	2005	**2006**	**2007**	**2008**
ln(CAD-USD exchange rate)	0.7492	0.9762	1.8072	1.4658 *
	(1.4720)	(1.4512)	(1.8542)	(0.7520)
Holiday	-0.0387	-0.1123 ***	0.1294	0.0552
	(0.0595)	(0.0326)	(0.0399) ***	(0.0502)
Weekend	0.0021	-0.0450 **	0.0435 ***	-0.0107
	(0.0190)	(0.0185)	(0.0155)	(0.0126)
Toronto's cooling degree	-0.0036	0.0071	0.0020	0.0048
days	(0.0056)	(0.0054)	(0.0055)	(0.0072)
Intercept	6.3141	6.7317	7.9045	8.5925
	(0.9894) ***	(0.2530) ***	(0.6501) ***	(0.7306) ***
N	184	184	184	182
Adj R^2	0.0729	0.1867	0.4076	0.2945

C. Metal Ore Mining				
	2005	**2006**	**2007**	**2008**
ln(price)	0.0415	0.1600 **	0.0618 **	-0.0173 **
	(0.0256)	(0.0737)	(0.0299)	(0.0073)
lag(ln(price))	0.0299 *	0.1661 ***	0.0915 ***	0.0056
	(0.0172)	(0.0602)	(0.0195)	(0.0116)
ln(Ontario's unemployment	-0.3774	-0.2166	0.3047	-0.0146
rate)	(0.6018)	(0.3201)	(0.3509)	(0.2534)
ln(CAD-USD exchange rate)	-4.0829 **	-4.1604	2.5340 *	-0.3221
	(1.7148)	(3.7588)	(1.4784)	(0.4863)
Holiday	0.0901 **	0.0792	0.0261	0.0005
	(0.0440)	(0.0506)	(0.0521)	(0.0179)

(Table 10 continues)

(Table 10 continued)

C. Metal Ore Mining								
	2005		**2006**		**2007**		**2008**	
Weekend	0.0401	***	0.1082	***	0.0573	***	0.0165	
	(0.0140)		(0.0336)		(0.0176)		(0.0135)	
Toronto's cooling degree	-0.0261	***	-0.0369	***	-0.0160	***	-0.0199	
days	(0.0069)		(0.0118)		(0.0059)		(0.0058)	
Intercept	7.5077	***	5.8091	***	4.9169	***	6.3447	***
	(1.4167)		(0.3771)		(0.6063)		(0.5111)	
N	184		184		184		182	
Adj R^2	0.4263		0.2344		0.2388		0.1842	

D. Motor Vehicle Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.3955	***	0.4337	***	0.3381	***	0.1572	***
	(0.1349)		(0.1180)		(0.0804)		(0.0525)	
lag(ln(price))	0.0666		0.1744	*	0.1250	**	0.0336	
	(0.0581)		(0.0934)		(0.0580)		(0.0306)	
ln(Ontario's unemployment	-4.1464	**	-0.8450	*	-2.0062	**	-2.1341	***
rate)	(2.0868)		(0.4653)		(0.8857)		(1.2056)	
ln(CAD-USD exchange rate)	-11.3497	*	-0.6542		-2.7294		2.5308	
	(5.9681)		(4.6833)		(4.8874)		(2.3463)	
Holiday	-0.0481		-0.2909	**	-0.1820		0.0002	
	(0.1912)		(0.1199)		(0.1614)		(0.0871)	
Weekend	-0.3338	***	-0.3462	***	-0.3057	***	-0.4119	***
	(0.0758)		(0.0825)		(0.0524)		(0.0489)	
Toronto's cooling degree	-0.0721	***	-0.0505	***	-0.0291		-0.0456	***
days	(0.0251)		(0.0158)		(0.0216)		(0.0250)	
Intercept	13.7509	***	4.6256	***	7.3334	***	8.2266	***
	(4.6118)		(0.3842)		(1.6206)		(2.3273)	
N	184		184		184		182	
Adj R^2	0.4899		0.5447		0.4655		0.4789	

(Table 10 continues)

(Table 10 continued)

E. Petroleum and Coal Products Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.2202	***	-0.1502	***	-0.1623	**	-0.0059	
	(0.0660)		(0.0480)		(0.0759)		(0.0039)	
lag(ln(price))	0.0909	**	-0.1106	***	-1.4447	***	-0.0065	
	(0.0396)		(0.0332)		(0.0496)		(0.0052)	
ln(Ontario's unemployment	0.3876		-1.0029	***	-0.9205		1.7972	***
rate)	(1.3906)		(0.2267)		(0.9249)		(0.3143)	
ln(CAD-USD exchange rate)	2.2760	*	-9.6377	***	-3.7193		1.1068	***
	(1.964)		(2.9506)		(6.3210)		(0.2794)	
Holiday	-0.0032		-0.0890	*	-0.0134		0.0123	
	(0.1012)		(0.0490)		(0.1565)		(0.0216)	
Weekend	0.0574	*	-0.0295		-0.0521		-0.0002	
	(0.0313)		(0.0231)		(0.0406)		(0.0067)	
Toronto’s cooling degree	-0.0435	***	0.0193	**	0.0168		-0.0094	***
days	(0.0118)		(0.0092)		(0.0188)		(0.0027)	
Intercept	2.7940		7.1551	***	8.4919	***	1.9953	***
	(3.1185)		(0.3308)		(2.1066)		(0.6189)	
N	184		184		184		182	
Adj R^2	0.2483		0.4215		0.1571		0.8154	
F. Pulp, Paper and Paperboard Mills								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0979	***	-0.2302	***	-0.1438	***	-0.0912	***
	(0.0254)		(0.0197)		(0.0144)		(0.0118)	
lag(ln(price))	0.1099	***	0.1457	***	0.1605	***	0.1011	***
	(0.0148)		(0.0170)		(0.0281)		(0.0100)	
ln(Ontario's unemployment	-0.6263		0.0878		0.1798		0.0485	
rate)	(0.4031)		(0.0662)		(0.1487)		(0.1366)	

(Table 10 continues)

(Table 10 continued)

F. Pulp, Paper and Paperboard Mills								
	2005		**2006**		**2007**		**2008**	
ln(CAD-USD exchange rate)	-1.3628		1.4206	**	2.3039	***	0.0203	
	(1.0363)		(0.6247)		(0.6127)		(0.4533)	
Holiday	0.0204		0.0387	**	0.1465	***	0.0441	
	(0.0601)		(0.0191)		(0.0163)		(0.0312)	
Weekend	0.0731	***	0.1087	***	0.1379	***	0.0667	***
	(0.0105)		(0.0105)		(0.0215)		(0.0100)	
Toronto's cooling degree	-0.0109	*	-0.0014		-0.0119	***	-0.0192	***
days	(0.0066)		(0.0029)		(0.0046)		(0.0048)	
Intercept	7.9662	***	6.3548		5.5222	***	6.0672	***
	(0.8707)		(0.1497)		(0.2270)		(0.2775)	
N	184		184		184		182	
Adj R^2	0.5616		0.7369		0.6362		0.5697	

G. Electric power generation, transmission, and distributions								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.2950	***	-0.4435	***	-0.2230	***	-0.2281	***
	(0.0510)		(0.0475)		(0.0340)		(0.0159)	
lag(ln(price))	0.3388	***	0.3507	***	0.2788	***	0.1824	***
	(0.0285)		(0.0351)		(0.0180)		(0.0186)	
ln(Ontario's unemployment	-0.0929		-0.7318	***	0.1070		-0.4052	
rate)	(0.5555)		(0.2086)		(0.2085)		(0.4433)	
ln(CAD-USD exchange rate)	-5.6906	***	3.6549	**	3.2290	**	-0.4861	
	(2.2026)		(1.6328)		(1.4294)		(0.7550)	
Holiday	0.0204		-0.0545		0.1409	**	0.1832	***
	(0.0288)		(0.0341)		(0.0615)		(0.0205)	
Weekend	0.0828	***	0.0659	**	0.0534	***	0.0207	
	(0.0187)		(0.0281)		(0.0204)		(0.0162)	

(Table 10 continues)

(Table 10 continued)

G. Electric power generation, transmission, and distributions								
	2005		**2006**		**2007**		**2008**	
Toronto's cooling degree	-0.0057		0.0069		-0.0190	**	-0.0156	
days	(0.0084)		(0.0074)		(0.0087)		(0.0101)	
Intercept	6.6450	***	6.7946	***	4.9353		6.4188	***
	(1.4921)		(0.3399)		(0.5007)		(0.8809)	
N	184		184		184		182	
Adj R^2	0.7130		0.6590		0.7004		0.6809	

Notes: Peak hours are defined as 7 am to 6:59pm, while off peak hours are from 7 pm to 6:59 am the next day. The lag of ln(price) is ln(price in previous period). Specifically, when the dependent variable is demand during peak hours (7 am to 6:59pm), the previous period is 12 am to 6:59 am (off-peak hours). When demand is for off peak hours (7 pm to 6:59 am), the previous period is 7 am to 6:59pm (peak hours). Three observations are dropped in the year 2008 because average price in previous period is negative and hence log cannot be taken. Ordinary Least Squares (OLS) estimates are presented with Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors with Bartlett kernel and bandwidth=24. Standard errors in parenthese. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month dummies are not included in this model.

Table 11: Instrumental Variables (IV) Estimates by Industry - Not Using Month Dummies, But Other Covariates

First Stage IV Regression (dependent variable = ln(price)*)*				
	2005	**2006**	**2007**	**2008**
ln(Ontario's unemployment rate)	1.9445 *	-0.5715	0.9735	-1.6196 **
	(1.0891)	(0.3770)	(0.6795)	(0.7957)
ln(CAD-USD exchange rate)	0.7074	11.4335 ***	4.9677	-0.1729
	(3.4008)	(4.0795)	(3.0533)	(1.7813)
Holiday	-0.3038	-0.1473	-0.1629 ***	-0.2314 **
	(0.1938)	(0.2072)	(0.0524)	(0.1090)
Weekend	-0.1837 ***	-0.1860 ***	-0.1676 ***	-0.2938 ***
	(0.0565)	(0.0359)	(0.0385)	(0.0985)
Toronto's cooling degree days	0.1710 ***	0.1350 ***	0.1775 ***	0.2619 ***
	(0.0134)	(0.0160)	(0.0219)	(0.0435)
NYC minus Toronto's cooling	0.0763 ***	0.0687 ***	0.0740 ***	0.1220 ***
degree days [instrument]	(0.0118)	(0.0113)	(0.0131)	(0.0254)
lag(Toronto's cooling degree	-0.0126	-0.0174 **	-0.0279 ***	-0.1318 *
days) [instrument]	(0.0145)	(0.0081)	(0.0079)	(0.0764)
lag(NYC minus Toronto's cooling	-0.0281 **	-0.0340 ***	-0.0655 ***	
degree days) [instrument]	(0.0118)	(0.0085)	(0.0214)	
Intercept	0.1317	3.5652 ***	1.5495	7.3746 ***
	(2.7065)	(0.3622)	(1.4245)	(1.3556)
N	184	184	184	182
Adj R^2	0.6030	0.5537	0.4620	0.4250
F statistic	14.07 ***	18.42 ***	15.29 ***	23.05 ***
First Stage IV Regression (dependent variable = lag(ln(price))*)*				
	2005	**2006**	**2007**	**2008**
ln(Ontario's unemployment rate)	1.6299 *	-0.5617	0.9083	-1.1868 *
	(0.9263)	(0.4340)	(0.6820)	(0.6901)
ln(CAD-USD exchange rate)	-0.2074	10.0717 **	5.6619 *	-0.9921
	(3.2626)	(4.4296)	(3.2397)	(1.4953)

(Table 11 continues)

(Table 11 continued)

First Stage IV Regression (dependent variable = lag(ln(price))*)*								
	2005		**2006**		**2007**		**2008**	
Holiday	-0.1208		-0.0649		-0.2186	***	-0.1763	
	(0.0816)		(0.2552)		(0.0737)		(0.1193)	
Weekend	-0.2078	***	-0.1792	***	-0.1988	***	-0.2610	***
	(0.0422)		(0.0254)		(0.0383)		(0.0871)	
Toronto's cooling degree days	0.0060		-0.0111		-0.0282	*	0.2497	***
	(0.0168)		(0.0119)		(0.0146)		(0.0391)	
NYC minus Toronto's cooling	-0.0034		-0.0448	***	-0.0379		0.1344	***
degree days [instrument]	(0.0114)		(0.0126)		(0.0256)		(0.0195)	
lag(Toronto’s cooling degree	0.1743	***	0.1441	***	0.1733	***	-0.0307	
days) [instrument]	(0.0153)		(0.0144)		(0.0217)		(0.0213)	
lag(NYC minus Toronto’s cooling	0.0704	***	0.0695	***	0.0678	***	-0.0593	***
degree days) [instrument]	(0.0091)		(0.0127)		(0.0134)		(0.0097)	
Intercept	0.8935		3.6969	***	1.6471		6.1010	***
	(2.3649)		(0.4276)		(1.4448)		(1.2567)	
N	184		184		184		182	
Adj R^2	0.5988		0.5549		0.4582		0.4415	
F statistic	55.00	***	117.33	***	25.70	***	47.36	***
Second Stage IV Regression								
A. Total Industrial								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0117		-0.1557	***	-0.0810	***	-0.0821	***
	(0.0367)		(0.0309)		(0.0253)		(0.0104)	
lag(ln(price))	0.0692	***	0.0723	***	0.0576	***	0.0208	**
	(0.0160)		(0.0112)		(0.0127)		(0.0101)	
ln(Ontario's unemployment rate)	-0.4067		-0.3042	***	-0.1467		-0.2217	
	(0.3802)		(0.0760)		(0.0989)		(0.1594)	

(Table 11 continues)

(Table 11 continued)

A. Total Industrial								
	2005		**2006**		**2007**		**2008**	
ln(CAD-USD exchange rate)	-1.8298	**	2.0320	*	1.8962	***	-0.0355	
	(0.9752)		(1.0784)		(0.5852)		(0.2317)	
Holiday	0.0025		-0.0378		0.0483	***	0.0192	**
	(0.0385)		(0.0404)		(0.0085)		(0.0098)	
Weekend	0.0181		-0.0071		0.0173	*	-0.0192	**
	(0.0138)		(0.0122)		(0.0082)		(0.0086)	
Toronto's cooling degree days	-0.0141	**	0.0053		-0.0001		0.0015	
	(0.0060)		(0.0047)		(0.0043)		(0.0038)	
Intercept	8.9001	***	8.5954	***	8.0926	***	8.5457	***
	(0.7846)		(0.0862)		(0.2065)		(0.3723)	
N	184		184		184		182	
Adj R^2	0.5335		0.4389		0.5885		0.3947	
Overidentification test								
Chi-sq(1)	3.090	*	0.196		1.742		0.051	
Endogeneity test								
Chi-sq(2)	0.895		4.743	*	1.576		5.352	*

B. Iron and Steel Mills and Ferro-Alloy Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0518		0.0050		0.0127		-0.1083	***
	(0.0335)		(0.0636)		(0.0397)		(0.0312)	
lag(ln(price))	0.0328		0.0856	**	0.0210		0.0313	
	(0.0280)		(0.0351)		(0.0324)		(0.0234)	
ln(Ontario's unemployment rate)	-0.0759		-0.2376		-0.9723	***	-1.2142	***
	(0.3790)		(0.1611)		(0.3180)		(0.3530)	
ln(CAD-USD exchange rate)	0.7911		-0.3881		1.3996		1.1735	
	(1.4639)		(2.5578)		(2.2086)		(0.7659)	

(Table 11 continues)

(Table 11 continued)

B. Iron and Steel Mills and Ferro-Alloy Manufacturing								
	2005		**2006**		**2007**		**2008**	
Holiday	-0.0496		-0.1015	*	0.1414	***	0.0295	
	(0.0668)		(0.0567)		(0.0496)		(0.0498)	
Weekend	-0.0016		-0.0264		0.0575	***	-0.0357	*
	(0.0212)		(0.0214)		(0.0189)		(0.0194)	
Toronto's cooling degree days	0.0011		0.0004		-0.0077		0.0241	**
	(0.0063)		(0.0089)		(0.0050)		(0.0118)	
Intercept	6.2790	***	6.4270	***	7.7829	***	9.1212	***
	(0.9788)		(0.2883)		(0.6717)		(0.7169)	
N	184		184		184		182	
Adj R^2	0.0572		0.1382		0.3737		0.1671	
Overidentification test								
Chi-sq(1)	2.928	*	0.092		0.731		1.926	
Endogeneity test								
Chi-sq(2)	1.029		2.009		0.913		1.822	
C. Metal Ore Mining								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.0640		-0.0820		-0.0619		-0.0844	***
	(0.0504)		(0.1053)		(0.0415)		(0.185)	
lag(ln(price))	-0.0029		-0.0068		0.0074		-0.0421	*
	(0.0321)		(0.0873)		(0.0330)		(0.0235)	
ln(Ontario's unemployment rate)	-0.3553		-0.4160		0.5164		-0.0793	
	(0.6731)		(0.4642)		(0.3757)		(0.2580)	
ln(CAD-USD exchange rate)	-4.0729	**	1.6045		3.7038	*	-0.6648	
	(1.8180)		(4.0908)		(2.1764)		(0.5420)	
Holiday	0.0942	*	0.0321		-0.0108		-0.0329	
	(0.0504)		(0.0966)		(0.0725)		(0.0217)	

(Table 11 continues)

(Table 11 continued)

C. Metal Ore Mining								
	2005		**2006**		**2007**		**2008**	
Weekend	0.0362	*	0.0285		0.0161		-0.0099	
	(0.0205)		(0.0400)		(0.0249)		(0.0158)	
Toronto's cooling degree days	-0.0295	**	-0.0059		0.0018		-0.0033	
	(0.0084)		(0.0105)		(0.0049)		(0.0059)	
Intercept	7.5108	***	7.1235	***	5.2245	***	6.9236	***
	(1.5067)		(0.8581)		(0.7957)		(0.5651)	
N	184		184		184		182	
Adj R^2	0.4040		0.0039		-0.0005		-0.1831	
Overidentification test								
Chi-sq(1)	4.107	**	0.512		0.442		0.627	
Endogeneity test								
Chi-sq(2)	0.150		3.924		3.736		3.800	

D. Motor Vehicle Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.4826	*	0.2437	*	0.0652		0.1785	***
	(0.2664)		(0.1290)		(0.1709)		(0.0583)	
lag(ln(price))	0.0389		0.0430		-0.0090		0.0052	
	(0.0916)		(0.0850)		(0.1177)		(0.0374)	
ln(Ontario's unemployment rate)	-4.3053	*	-0.9998	*	-1.5947		-2.1381	*
	(2.2161)		(0.5983)		(0.9951)		(1.1786)	
ln(CAD-USD exchange rate)	-11.4588	*	3.8009		-0.5093		2.4705	
	(5.9694)		(6.1709)		(5.8095)		(2.3951)	
Holiday	-0.0194		-0.3276	*	-0.2506		-0.0104	
	(0.2069)		(0.1990)		(0.1917)		(0.0995)	
Weekend	-0.3243	***	-0.4080	***	-0.3833	***	-0.4122	***
	(0.0906)		(0.0679)		(0.0569)		(0.0494)	

(Table 11 continues)

(Table 11 continued)

D. Motor Vehicle Manufacturing								
	2005		**2006**		**2007**		**2008**	
Toronto's cooling degree days	-0.0845	**	-0.0262	*	0.0107		-0.0519	*
	(0.0397)		(0.0140)		(0.0151)		(0.0304)	
Intercept	13.8430	***	5.6454	***	7.9419	***	8.2659	***
	(4.6037)		(0.7084)		(2.0395)		(2.0766)	
N	184		184		184		182	
Adj R^2	0.4833		0.5126		0.3867		0.4756	
Overidentification test								
Chi-sq(1)	3.480	*	2.465		0.074		2.847	*
Endogeneity test								
Chi-sq(2)	2.120		1.166		1.573		0.085	

E. Petroleum and Coal Products Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.3076	**	-0.1504		-0.0697		-0.0378	*
	(0.1312)		(0.1075)		(0.0923)		(0.0226)	
lag(ln(price))	0.0399		-0.0519		-0.0792		-0.0399	**
	(0.0536)		(0.0807)		(0.0929)		(0.0204)	
ln(Ontario's unemployment rate)	0.2858		-0.9786	***	-1.0817		1.7604	***
	(1.4217)		(0.2790)		(1.0933)		(0.3200)	
ln(CAD-USD exchange rate)	2.2014		8.6829	**	-4.6119		0.9025	***
	(4.1586)		(4.3880)		(7.2939)		(0.3513)	
Holiday	0.0227		-0.0840	**	0.0149		-0.0087	
	(0.1001)		(0.0390)		(0.1978)		(0.0266)	
Weekend	0.0612		-0.0189		-0.0206	***	-0.0149	
	(0.0411)		(0.0395)		(0.0475)		(0.0105)	
Toronto's cooling degree days	-0.0561	***	0.0190	**	0.0034		-0.0018	
	(0.0171)		(0.0095)		(0.0064)		(0.0049)	

(Table 11 continues)

(Table 11 continued)

E. Petroleum and Coal Products Manufacturing								
	2005		**2006**		**2007**		**2008**	
Intercept	2.8676		6.9903	***	8.2583	***	3.3251	***
	(3.0919)		(0.6603)		(1.8923)		(0.6549)	
N	184		184		184		182	
Adj R^2	0.2133		0.4031		0.1331		0.7657	
Overidentification test								
Chi-sq(1)	4.309	**	1.981		0.117		0.046	
Endogeneity test								
Chi-sq(2)	0.564		1.619		1.291		3.897	

F. Pulp, Paper, and Paperboard Mills								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0782	*	-0.3757	***	-0.1793	***	-0.0914	***
	(0.0476)		(0.0446)		(0.0634)		(0.0276)	
lag(ln(price))	0.0954	***	0.1158	***	0.1788	***	0.1226	***
	(0.0194)		(0.0171)		(0.0352)		(0.0096)	
ln(Ontario's unemployment rate)	-0.6420		-0.0012		0.1947		0.0604	
	(0.4428)		(0.1100)		(0.1426)		(0.1380)	
ln(CAD-USD exchange rate)	-1.3753		3.6805	***	2.3418	***	0.1030	
	(1.0820)		(1.1263)		(0.7835)		(0.4430)	
Holiday	0.0259		0.0167		0.1466	***	0.0545	
	(0.0562)		(0.0600)		(0.0223)		(0.0343)	
Weekend	0.0732	***	0.0742	***	0.1371	***	0.0709	***
	(0.0133)		(0.0151)		(0.0243)		(0.0137)	
Toronto's cooling degree days	-0.0137	*	0.0168	***	-0.0064		-0.0186	**
	(0.0081)		(0.0043)		(0.0128)		(0.0076)	
Intercept	7.9805	***	6.9365	***	5.5525	***	5.9587	***
	(0.9003)		(0.2332)		(0.3132)		(0.3211)	

(Table 11 continues)

(Table 11 continued)

F. Pulp, Paper, and Paperboard Mills								
	2005		**2006**		**2007**		**2008**	
N	184		184		184		182	
Adj R^2	0.5555		0.6403		0.6266		0.5608	
Overidentification test								
Chi-sq(1)	0.919		1.842		1.216		1.193	
Endogeneity test								
Chi-sq(2)	0.522		3.099		3.104		1.126	

G. Electric Power Generation, Transmission, and Distribution								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.4757	***	-0.7345	***	-0.4234	***	-0.3695	***
	(0.0764)		(0.1654)		(0.1051)		(0.0364)	
lag(ln(price))	0.3590	***	0.4330	***	0.2599	***	0.1399	***
	(0.0361)		(0.0672)		(0.0491)		(0.0292)	
ln(Ontario's unemployment rate)	0.3280		-0.8504	***	0.3231		-0.5090	
	(0.5241)		(0.2028)		(0.2852)		(0.4688)	
ln(CAD-USD exchange rate)	-5.409	***	5.8539	*	4.3004	**	-0.9833	
	(1.9054)		(3.3829)		(1.9064)		(0.6258)	
Holiday	-0.0439		-0.0864		0.1106	**	0.1412	***
	(0.0516)		(0.0653)		(0.0504)		(0.0289)	
Weekend	0.0540	**	0.0229		0.171		-0.0234	
	(0.0242)		(0.0469)		(0.0352)		(0.0327)	
Toronto's cooling degree days	0.0198	*	0.0427	**	0.0110		0.0207	*
	(0.0109)		(0.0202)		(0.0167)		(0.0126)	
Intercept	6.4240	***	7.5565	***	5.2732	***	7.3421	***
	(1.3566)		(0.7526)		(0.5024)		(1.0126)	
N	184		184		184		182	
Adj R^2	0.6612		0.5420		0.5983		0.5844	

(Table 11 continues)

(Table 11 continued)

G. Electric Power Generation, Transmission, and Distribution				
	2005	**2006**	**2007**	**2008**
Overidentification test				
Chi-sq(1)	0.320	0.073	2.241	2.671
Endogeneity test				
Chi-sq(2)	5.078 *	5.393	2.003	2.508

Notes: Peak hours are defined as 7 am to 6:59pm, while off peak hours are from 7 pm to 6:59 am the next day. The lag of ln(price) is ln(price in previous period). Specifically, when the dependent variable is demand during peak hours (7 am to 6:59pm), the previous period is 12 am to 6:59 am (off-peak hours). When demand is for off peak hours (7 pm to 6:59 am), the previous period is 7 am to 6:59pm (peak hours). Three observations are dropped in the year 2008 because average price in previous period is negative and hence log cannot be taken. IV estimation uses the difference of New York's and Toronto's cooling degree days as an instrument for ln(price), lag Toronto's cooling degree days and lag of the difference of New York's and Toronto's cooling degree days as an instrument for lag of ln(price). HAC standard errors with Bartlett kernel and bandwidth=24 are presented. Standard errors in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month dummies are not included in this model.

Table 12: OLS Estimation with All Years Pooled

	A.		B.		C.		D.		E.		F.		G.	
ln(price)	-0.0321	***	-0.0288	***	0.0390	*	0.2710	***	-0.0009		-0.1242	***	-0.2468	***
	(0.0053)		(0.0109)		(0.0202)		(0.0450)		(0.0327)		(0.0119)		(0.0206)	
lag(ln(price))	0.0652	***	0.0158		0.0578	***	0.0820	***	-0.0168		0.1214	***	0.2758	***
	(0.0067)		(0.0105)		(0.0181)		(0.0316)		(0.0254)		(0.0090)		(0.0221)	
ln(Ontario's	-0.1940	***	-0.4590	***	-0.1175		-1.1772	***	-0.1761		0.0489		-0.2186	
unemployment rate)	(0.0514)		(0.1209)		(0.2407)		(0.3474)		(0.3136)		(0.0646)		(0.1802)	
ln(CAD-USD	-0.0357		1.2015	**	-0.9398		1.1903		0.9803		0.3511		-1.6129	
exchange rate)	(0.2606)		(0.5816)		(0.6642)		(1.6711)		(1.1635)		(0.3092)		(0.9959)	
Holiday	0.0182		0.0018		0.0538	**	-0.1903	**	-0.0046		0.0584	**	0.0977	**
	(0.0165)		(0.0332)		(0.0247)		(0.0961)		(0.0522)		(0.0273)		(0.0404)	
Weekend	0.0143	***	0.0008		0.0480	***	-0.3617	***	0.0034		0.0967	***	0.0625	***
	(0.0045)		(0.0103)		(0.0122)		(0.0332)		(0.0149)		(0.0087)		(0.0132)	
Toronto's cooling	-0.0099	***	0.0002		-0.0224	***	-0.0406	***	-0.0081		-0.0110	***	-0.0143	***
degree days	(0.0016)		(0.0032)		(0.0047)		(0.0118)		(0.0084)		(0.0031)		(0.0049)	
Intercept	8.1232	***	7.1740	***	6.1340	***	5.7806	***	5.8277		6.0948	***	5.7916	
	(0.0974)		(0.2363)		(0.3993)		(0.5448)		(0.6619)		(0.1224)		(0.3615)	
N	734		734		734		734		734		734		734	
Adj R^2	0.7135		0.3658		0.1926		0.5199		0.1051		0.8397		0.6211	

Notes: Peak hours are defined as 7 am to 6:59pm, while off peak hours are from 7 pm to 6:59 am the next day. The lag of ln(price) is ln(price in previous period). Specifically, when the dependent variable is demand during peak hours (7 am to 6:59pm), the previous period is 12 am to 6:59 am (off-peak hours). When demand is for off peak hours (7 pm to 6:59 am), the previous period is 7 am to 6:59pm (peak hours). Three observations are dropped in the year 2008 because average price in previous period is negative and hence log cannot be taken. Ordinary Least Squares (OLS) estimates are presented with Heteroskedasticity and Autocorrelation Consistent (HAC) standard errors with Bartlett kernel and bandwidth=24. Standard errors in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month dummies are not included in this model. The estimates are obtained by pooling all data from 2005-2008. Year dummies (base year 2008) are included in the model but not shown in the table. Finally, A=Total Industrial, B=Iron and Steel Mills and Ferro-Alloy Manufacturing, C = Metal Ore Mining, D = Motor Vehicle Manufacturing, E = Petroleum and Coal Products Manufacturing, F = Pulp, Paper and Paperboard Mills, G = Electric Power Generation, Transmission and Distribution.

Table 13: Ordinary Least Squares Estimates by Industry Using Hourly Data

A. Total Industrial								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0627	***	-0.0660	***	-0.0504	***	-0.0324	***
	(0.0040)		(0.0054)		(0.0046)		(0.0023)	
lag(ln(avg price))	0.0634	***	0.0904	***	0.0626	***	0.0338	***
	(0.0057)		(0.0101)		(0.0070)		(0.0044)	
Intercept	7.9995	***	7.8283	***	7.7791	***	7.8638	***
	(0.0338)		(0.0520)		(0.0377)		(0.0212)	
N	2208		2208		2208		2176	
Adj R^2	0.5364		0.5168		0.4490		0.4055	
B. Iron and Steel Mills and Ferro-Alloy Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0206	**	0.0002		-0.0198	**	-0.0145	***
	(0.0095)		(0.0120)		(0.0094)		(0.0054)	
lag(ln(avg price))	0.0209		0.0636	***	0.0157		-0.0031	
	(0.0156)		(0.0159)		(0.0158)		(0.0118)	
Intercept	6.1961	***	5.9579	***	6.0761	***	6.3495	***
	(0.0878)		(0.0938)		(0.0852)		(0.0590)	
N	2208		2208		2208		2176	
Adj R^2	0.0371		0.2320		0.3125		0.1852	
C. Metal Ore Mining								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.0371	***	0.0032		-0.0096		-0.0114	***
	(0.0064)		(0.0180)		(0.0066)		(0.0038)	
lag(ln(avg price))	0.0061		0.0931	***	0.0354	***	0.0039	
	(0.0100)		(0.0272)		(0.0125)		(0.0076)	
Intercept	6.4617	***	5.9232	***	6.2218	***	6.2829	***
	(0.0632)		(0.1647)		(0.0699)		(0.0400)	
N	2208		2208		2208		2176	
Adj R^2	0.4457		0.4872		0.4418		0.0240	

(Table 13 continues)

(Table 13 continued)

D. Motor Vehicle Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.1282	***	0.2450	***	0.1884	***	0.1010	***
	(0.0266)		(0.0337)		(0.0272)		(0.0175)	
lag(ln(avg price))	0.1301	**	0.2561	***	0.1653	***	0.0907	**
	(0.0512)		(0.0529)		(0.0475)		(0.0387)	
Intercept	4.1827	***	3.3165	***	3.6847	***	4.0910	***
	(0.3162)		(0.3078)		(0.2778)		(0.1892)	
N	2208		2208		2208		2176	
Adj R^2	0.3352		0.3488		0.2765		0.1385	
E. Petroleum and Coal Products Manufacturing								
	2005		**2006**		**2007**		**2008**	
ln(price)	0.0370	**	-0.0105		0.0109	**	-0.0057	**
	(0.0146)		(0.0116)		(0.0046)		(0.0026)	
lag(ln(avg price))	0.0740	***	-0.0182		0.0123		-0.0065	
	(0.0243)		(0.0150)		(0.0112)		(0.0049)	
Intercept	4.9202	***	5.2821	***	4.9337	***	5.5523	***
	(0.1619)		(0.0993)		(0.0587)		(0.0262)	
N	2208		2208		2208		2176	
Adj R^2	0.2213		0.7858		0.9479		0.8055	
F. Pulp, Paper and Paperboard Mills								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.1295	***	-0.1934	***	-0.1699	***	-0.0749	***
	(0.0075)		(0.0113)		(0.0143)		(0.0064)	
lag(ln(avg price))	0.0800	***	0.1162	***	0.0981	***	0.0872	***
	(0.0127)		(0.0197)		(0.0195)		(0.0109)	
Intercept	6.7383	***	6.6780	***	6.3889	***	6.1567	***
	(0.0694)		(0.0941)		(0.1016)		(0.0472)	
N	2208		2208		2208		2176	
Adj R^2	0.4312		0.4182		0.3539		0.3482	

(Table 13 conitnues)

(Table 13 continued)

G. Electric Power Generation, Transmission and Distribution								
	2005		**2006**		**2007**		**2008**	
ln(price)	-0.3331	***	-0.3839	***	-0.2717	***	-0.1843	***
	(0.0176)		(0.0173)		(0.0148)		(0.0086)	
lag(ln(avg price))	0.2683	***	0.3300	***	0.2172	***	0.1447	***
	(0.0243)		(0.0265)		(0.0172)		(0.0154)	
Intercept	5.8393	***	5.5601	***	5.7512	***	5.5305	***
	(0.1471)		(0.1297)		(0.0947)		(0.0711)	
N	2208		2208		2208		2176	
Adj R^2	0.5502		0.5424		0.5207		0.5279	

Notes: Hourly data are used. Peak hours are defined as 7 am to 6:59pm, while off peak hours are from 7 pm to 6:59 am the next day. lag(ln(avg price)) is ln(average price in previous peak or off-peak period). Specifically, when the dependent variable is hourly demand during peak hours (7 am to 6:59pm), the previous period is 12 am to 6:59 am (off-peak hours). When demand is for off peak hours (7 pm to 6:59pm), the previous period is 7 am to 6:59pm (peak hours). Some observations are dropped in the year 2008 because prices are negative and hence log cannot be taken. Ordinary Least Square with standard errors clustered by date are used to correct for Heteroskedasticity and Serial Correlation. Standard errors in parentheses. *, ** and *** indicate significant at 10%, 5% and 1% level respectively. Month dummies are included in the model but not shown in the table.

Table 14: Price Elasticities from Chapters 2 and 3

A. Total Industrial

		2005		2006		2007		2008	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	-0.008	-0.010	-0.024	-0.055	-0.019	-0.038	-0.012	-0.042
	o	-0.015	-0.010	-0.042	-0.055	-0.036	-0.038	-0.024	-0.042
cross-price	po	0.008	0.077	0.024	0.096	0.019	0.071	0.012	0.036
	op	0.015	0.077	0.042	0.096	0.036	0.071	0.024	0.036

B. Iron and Steel Mills and Ferro-Alloy Manufacturing

		2005		2006		2007		2008	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	-0.008	-0.019	-0.019	-0.047	-0.020	-0.053	-0.003	-0.032
	o	-0.015	-0.019	-0.034	-0.047	-0.036	-0.053	-0.005	-0.032
cross-price	po	0.008	0.023	0.019	0.041	0.020	0.007	0.003	-0.002
	op	0.015	0.023	0.034	0.041	0.036	0.007	0.005	-0.002

C. Metal Ore Mining

		2005		2006		2007		2008	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	0.000	0.042	-0.032	0.160	-0.019	0.062	-0.005	-0.017
	o	0.000	0.042	-0.053	0.160	-0.036	0.062	-0.010	-0.017
cross-price	po	0.000	0.030	0.032	0.166	0.019	0.092	0.005	0.006
	op	0.000	0.030	0.053	0.166	0.036	0.092	0.010	0.006

D. Motor Vehicle Manufacturing

		2005		2006		2007		2008	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	-0.014	0.396	-0.027	0.434	-0.007	0.338	0.000	0.157
	o	-0.028	0.396	-0.055	0.434	-0.019	0.338	0.000	0.157
cross-price	po	0.014	0.067	0.027	0.174	0.007	0.125	0.000	0.034
	op	0.028	0.067	0.055	0.174	0.019	0.125	0.000	0.034

(Table 14 continues)

(Table 14 continued)

E. Petroleum and Coal Products Manufacturing									
		2005		**2006**		**2007**		**2008**	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	0.00	0.22	-0.03	-0.15	-0.03	-0.16	-0.01	-0.01
	o	0.00	0.22	-0.04	-0.15	-0.05	-0.16	-0.03	-0.01
cross-price	po	0.00	0.09	0.03	-0.11	0.03	-1.44	0.01	-0.01
	op	0.00	0.09	0.04	-0.11	0.05	-1.44	0.03	-0.01
F. Pulp, Paper and Paperboard Mills									
		2005		**2006**		**2007**		**2008**	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	-0.028	-0.098	-0.035	-0.230	0.000	-0.144	-0.014	-0.091
	o	-0.046	-0.098	-0.062	-0.230	0.000	-0.144	-0.038	-0.091
cross-price	po	0.028	0.110	0.035	0.146	0.000	0.161	0.014	0.101
	op	0.046	0.110	0.062	0.146	0.000	0.161	0.038	0.101
G. Electric Power Generation, Transmission and Distribution									
		2005		**2006**		**2007**		**2008**	
		Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3	Ch 2	Ch 3
own-price	p	-0.009	-0.295	0.000	-0.444	-0.034	-0.223	-0.032	-0.228
	o	-0.014	-0.295	0.000	-0.444	-0.068	-0.223	-0.057	-0.228
cross-price	po	0.009	0.339	0.000	0.351	0.034	0.279	0.032	0.182
	op	0.014	0.339	0.000	0.351	0.068	0.279	0.057	0.182

Notes: Chapter 2 Price Elasticities are computed based on equations (11) and (12) and evaluated at the mean peak-hours HOEP and mean off-peak-hours HOEP. Chapter 3 Price Elasticities are from Table 10.

Table 15: Mean Number and Proportion of Retail Gasoline Outlets Across Waves

Brand	Calgary		Regina		Saskatoon		Toronto		Winnipeg	
	Mean #	Mean Prop	Mean #	Mean Prop	Mean #	Mean Prop	Mean #	Mean Prop	Mean #	Mean Prop
ESSO	43.33	17.88%	11.00	23.91%	10.00	23.32%	156.40	26.75%	25.33	20.71%
PETROCAN	38.00	15.68%	8.00	17.39%	6.00	13.99%	143.40	24.53%	23.00	18.80%
SHELL	37.33	15.41%	9.00	19.57%	7.33	17.06%	120.40	20.60%	31.00	25.34%
CO-OP (WEST)	21.33	8.80%	1.00	2.17%	2.00	4.66%			9.00	7.36%
HUSKY	21.67	8.94%	2.00	4.35%	3.00	6.83%	2.00	0.34%	3.00	2.45%
SUNOCO							71.80	12.28%		
Independent Retailers		33.29%		32.61%		34.14%		15.5%		25.34%

Table 16: Summary Statistics for Chapter 4

Variable		Obs	Mean	Std. Dev.	Min	Max
Gas Price (cents per litre)		3327	94.8053	10.7761	71.5	121.9
Station Sales		3327	513542.4	276382.3	8701	1721542
Station Market Share (%)		3327	15.2984	14.3489	0.1353	100
Competitors	(FSA)	3327	6.4926	4.4688	0	17
	(3km)	3327	7.6616	3.6013	0	21
Competitors (3km)	Vertically Integrated	3327	6.3153	3.2216	0	19
	Independent	3327	1.3463	1.2835	0	8
Competitors (3km)	Same Brand	3327	1.1638	1.2446	0	7
	Other Brands	3327	6.4977	3.1617	0	20
Competitors (3km)	Other Brands – Vertically Integrated	3327	5.1728	2.7506	0	18
Competitors (3km)	Other Brands – Independent	3327	1.3249	1.2506	0	8
Firm Type Dummy	- National Vertically Integrated	3327	0.6946	0.4606	0	1
	- Regional	3327	0.1395	0.3465	0	1
	- Independent	3327	0.1659	0.3721	0	1
Crude Oil Price (Current) in cents per liter		3327	45.5482	3.6052	38.1	52.794
Crude Oil Price (Past Month) in cents per liter		3327	45.6346	3.0970	39.597	50.337

(Table 16 continues)

(Table 16 continued)

Variable		**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Number of Self Service Pumps		3327	27.5083	11.2774	2	73
Convenience Store Size Dummies	- No Store	3327	0.0349	0.1835	0	1
	- Small	3327	0.2982	0.4575	0	1
	- Medium	3327	0.3940	0.4887	0	1
	- Large	3327	0.2729	0.4455	0	1
Car Wash Dummies		3327	0.4232	0.4941	0	1
Distance from Highway (in kilometers)		3327	3.2919	2.2954	0.1	12.7
Population (10,000)		3327	5.2578	2.9571	0.0090	17.5993
Mean HH Income (1,000)		3327	84.3054	22.3312	36.2161	168.0911
Unemployment Rate (%)		3327	6.3836	1.6064	3.0187	10.4559
% Driving to Work		3327	65.7473	11.6800	22.0108	91.7928
# Business Addresses		3327	1.5349	1.1811	0	8.4792
# Residential Addresses		3327	17.3780	11.3489	0	70.3590

Table 17: Baseline OLS Estimates of the Number of Stations on Market Share

	(1) Sellers by FSA		(2) Sellers by 3 km		(3) Sellers by 3 km	
Number of Competitors in 3 km	-3.5586	***	-2.2928	***	-2.2911	***
radius	(0.2577)		(0 .2117)		(0 .2132)	
Crude Oil Price	-0.5150		-0.0271		-0.0187	
Current Day	(0.3943)		(0 .0941)		(0 .0907)	
Crude Oil Price	0.6681		-0.0310		-0.0245	
Past Calendar Month	(0.6437)		(0 .1747)		(0 .1754)	
National Vertically	1.9917		3.8488	*		
Integrated Dummy	(2.4793)		(2.0281)			
Regional Vertically	-4.6252		0.7428			
Integrated Dummy	(3.3611)		(2.2555)			
Number of Self-serve	0.3861	***	0.2601	***	0 .2745	***
Pumps	(0.0586)		(0 .0344)		(0 .0239)	
Convenience	0.8748		-0.0451		-0.5171	
Store (Small)	(4.1393)		(2.7469)		(2.7153)	
Convenience	0.8912		1.2933		0.5340	
Store (Medium)	(4.2714)		(2.9391)		(2.7915)	
Convenience	1.0993		1.5857		1.3778	
Store (Large)	(4.2102)		(3.1627)		(3.1018)	
Car Wash	0.9854		-0.3839		-0.2016	
	(1.5552)		(0.9264)		(0 .8185)	

(Table 17 continues)

(Table 17 continued)

	(1) Sellers by FSA	(2) Sellers by 3 km	(3) Sellers by 3 km
Distance from Highway, Population, Mean Household Income, Unemployment Rate, % Driving to Work	Yes ***	Yes **	Yes ***
Day of Week FE	Yes *	Yes **	Yes **
Month FE	Yes	Yes	Yes
City FE	Yes	Yes *	Yes *
Firm FE	No	No	Yes **
Intercept	84.8301 **	28.3230 ***	28.7112 ***
	(36.7577)	(8.5818)	(8.4122)
Adjusted R^2	0.2699	0.4476	0.4683

Notes: The dependent variable in all regressions is the market share of each station. The data are for stations in 5 Canadian cities: Calgary, Regina, Saskatoon, Toronto and Winnipeg. The data were collected for: January, March, and May for Calgary, Saskatoon, and Regina; December, February, and April for Winnipeg; and for each month from January to May for Toronto. Column 1 focuses on the effect of the number of all competitors within a station's Forward Sorting Area (FSA) while the other columns investigate the impact of the number of outlets within a 3 km radius. Bootstrapped standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level. Bootstrapped s.e. are based on Cameron et al. (2008).

Table 18: Instrumental Variable Estimates of the Effects of the Number of Stations (in 3-km Radius) on Market Share

	(1)		(2)	
	1st Stage		**2nd Stage**	
Dependent Variable	Number of Competitors in 3-km Radius		Station Market Share	
# Business addresses	0.4663	***		
	(0.1389)			
# Residential addresses	-0.1003	***		
	(0.0360)			
Number of Competitors in 3 km radius			-4.4419	***
			(0.8417)	
Crude Oil Price	0 .1301	***	0.2282	
Current Day	(0.0316)		(0.1989)	
Crude Oil Price	-0.0298		-0.07111	
Past Calendar Month	(0.0317)		(0.1831)	
National Vertically Integrated	-0.6350	**	2.4771	
Firm	(0.2956)		(1.7196)	
Regional Vertically Integrated	0.0290		0.8076	
Firm	(0.5493)		(2.0292)	
Number of Self-serve	0.0101		0.2877	***
Pumps	(0.0181)		(0.0541)	
Convenience	0.7127		1.4496	
Store (Small)	(0.5197)		(2.9440)	
Convenience	0.3096		1.8867	
Store (Medium)	(0.5622)		(3.2568)	
Convenience	-0.0129		1.4847	
Store (Large)	(0.7526)		(3.7471)	

(Table 18 continues)

(Table 18 continued)

	(1)		(2)	
	1st Stage		**2nd Stage**	
Dependent Variable	Number of Competitors in 3-km Radius		Station Market Share	
Car Wash	0.1492		-0.1049	
	(0.2821)		(0.9130)	
Distance from Highway, Population, Mean Household Income, Unemployment Rate, % Driving to Work	Yes	***	Yes	**
Day of Week FE	Yes	***	Yes	***
Month FE	Yes	***	Yes	
City FE	Yes	***	Yes	***
Firm FE	No		No	
Intercept	0.5821		30.9012	***
	(2.7518)		(8.8351)	
Adjusted R^2	0.3488		0.2606	
Test of Relevance				
F-statistic	15.32	***		
Overidentification Test				
Chi-sq(1)			0.022	

<u>Notes:</u> The data are for stations in 5 Canadian cities: Calgary, Regina, Saskatoon, Toronto and Winnipeg. The data were collected for: January, March, and May for Calgary, Saskatoon, and Regina; December, February, and April for Winnipeg; and for each month from January to May for Toronto. The first column consists of first stage regression estimates using the number of local businesses and residences as instruments for the number of competitors in a 3 km radius. Column 2 contains corresponding second stage results. Bootstrap standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level. Bootstrapped s.e. are based on Cameron et al. (2008).

Table 19: OLS Estimates of the Effects of the Number of Stations (in 3-km Radius) on Station Market Share by Firm Type and Brand

	(1)	(2)	(3)	(4)	(5)	(6)
Number of Competitors (3 km	-1.6491***	-1.6423***				
radius)	(0.3294)	(0.3259)				
Vertically Integrated (VI)			-1.5776***	-1.5544***		
Competitors (3 km radius)			(0.2988)	(0.2929)		
Independent Competitors (3			-1.9906***	-2.0744***		
km radius)			(0.7614)	(0.7710)		
Competitors					-2.6298***	-2.7487***
of Same Brand					(0.5158)	(0.5252)
VI Competitors					-2.3031***	-2.2191***
of Different Brands					(0.2463)	(0.2291)
Independent Competitors					-2.0335***	-2.0876***
of Different Brands					(0.3205)	(0.2963)
Competitors	-0.8115**	-0.7885*				
* VI Dummy	(0.4270)	(0.4220)				
VI Competitors			-0.9654**	-0.9469**		
* VI Dummy			(0.4387)	(0.4355)		
Independent Competitors			-0.0516	-0.0107		
* VI Dummy			(0.7779)	(0.8129)		
Crude Oil Price	-0.0009	-0.0037	-0.0107	-0.0136	-0.0126	-0.0137
Current Day	(0.0911)	(0.0871)	(0.0887)	(0.0850)	(0.0969)	(0.0933)
Crude Oil Price	-0.0240	-0.0177	-0.0171	-0.0130	-0.0298	-0.0277
Past Calendar Month	(0.1758)	(0.1759)	(0.1767)	(0.1765)	(0.1724)	(0.1728)
Dummy for VI Firm	Yes**	No	Yes**	No	Yes*	No
Firm FE	No	Yes*	No	Yes*	No	Yes**
# Self-serve Pumps, Convenience Store (Small), Convenience Store (Medium), Convenience Store (Large), Car Wash	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***
Distance from Highway, Population, Mean Household Income, Unemployment Rate, % Driving to Work	Yes**	Yes**	Yes**	Yes***	Yes***	Yes***

(Table 19 continues)

(Table 19 continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Day of Week FE	Yes **	Yes **	Yes **	Yes **	Yes **	Yes **
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes *	Yes	Yes	Yes *	Yes
Intercept	21.1932 **	22.3790 **	19.9055 *	21.7533 **	25.3491 ***	26.8931 ***
	(9.5829)	(9.1620)	(10.6334)	(9.8380)	(9.2900)	(8.5356)
Adjusted R^2	0.4482	0.4735	0.4492	0.4743	0.4434	0.4694

Notes: The data are for stations in 5 Canadian cities: Calgary, Regina, Saskatoon, Toronto and Winnipeg. Column 1 and 2 focus on the effects of competitors in a 3 km radius interacted with a vertically integrated firm dummy. Columns 3 and 4 focus on local competitors by firm type (vertically integrated or independent) and interactions of these covariates with a vertical integrated dummy. Finally, columns 5 and 6 contain corresponding results of local competitors (within a 3 km radius) by brand. Bootstrapped standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level.

Table 20: OLS Estimates of the Effects of the Number of Statiions (in 3-km Radius) on Natural Logarithm of Station Sales by Firm Type and Brand (Log-Log) Model

	(1)	(2)	(3)	(4)	(5)	(6)
Number of Competitors (3	-0.0290	-0.0268				
km radius)	(0.1010)	(0.1110)				
Vertically Integrated (VI)			-0.0522	-0.0483		
Competitors (3 km radius)			(0.0476)	(0.0440)		
Independent Competitors (3			0.0049	0.0040		
km radius)			(0.0124)	(0.0131)		
Competitors					-0.0078***	-0.0098***
of Same Brand					(0.0030)	(0.0012)
VI Competitors					-0.0100	-0.0023
of Different Brands					(0.0147)	(0.0052)
Independent Competitors					-0.0033	-0.0037**
of Different Brands					(0.0034)	(0.0018)
Competitors	0.0083	0.0144				
* VI Dummy	(0.1010)	(0.1090)				
VI Competitors			0.0342	0.0386		
* VI Dummy			(0.0479)	(0.0433)		
Independent Competitors			-0.0098	-0.0092		
* VI Dummy			(0.0130)	(0.0132)		
Crude Oil Price	-0.3020*	-0.3410***	-0.2620	-0.2980***	-0.2540	-0.2860***
Current Day	(0.1590)	(0.0828)	(0.1630)	(0.0858)	(0.1670)	(0.0889)
Crude Oil Price	5.5430***	5.5730***	5.5270***	5.5630***	5.5370***	5.5670***
Past Calendar Month	(0.6800)	(0.3250)	(0.6840)	(0.3260)	(0.6730)	(0.3220)
Dummy for VI	Yes	No	Yes	No	Yes**	No
Firm FE	No	Yes*	No	Yes**	No	Yes***
# Self-serve Pumps, Convenience Store (Small), Convenience Store (Med), Convenience Store (Large), Car Wash	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***
Distance from Highway, Population, Mean Household Income, Unemployment Rate, % Driving to Work	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***

(Table 20 continues)

(Table 20 continued)

	(1)		(2)		(3)		(4)		(5)		(6)	
Day of Week FE	Yes		Yes	***	Yes		Yes	***	Yes		Yes	***
Month FE	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***
City FE	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***
Intercept	-9.189	***	-8.982	***	-9.265	***	-9.022	***	-9.206	***	-8.950	***
	(2.374)		(1.180)		(2.249)		(1.091)		(2.244)		(1.062)	
Adjusted R^2	0.4535		0.4868		0.4562		0.4892		0.4564		0.4916	

Notes: Column 1 and 2 focus on the effects of competitors in a 3 km radius interacted with a vertically integrated firm dummy. Columns 3 and 4 focus on local competitors by firm type (vertically integrated or independent) and interactions of these covariates with a vertical integrated dummy. Finally, columns 5 and 6 contain corresponding results of local competitors (within a 3 km radius) by brand. Bootstrapped standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5% level and *** at the 1% level.

Table 21: OLS Estimates of the Effects of the Number of Stations (in 3-km Radius) on Outlet Specific Prices by Firm Type and Brand

	(1)	(2)	(3)	(4)	(5)	(6)
Competitors in 3 km radius	-0.0348	-0.0382				
	(0.0321)	(0.0326)				
Vertically Integrated (VI)			-0.0271	-0.0244		
Competitors in 3 km radius			(0.0265)	(0.0276)		
Independent Competitors in 3			-0.0357	-0.0557		
km radius			(0.1027)	(0.1093)		
Competitors					-0.1326**	-0.1478***
of Same Brand					(0.0529)	(0.0541)
VI Competitors					-0.0441***	-0.0344**
of Different Brands					(0.0129)	(0.0141)
Independent Competitors					0.0737**	0.0613*
of Different Brands					(0.0369)	(0.0340)
Competitors	0.0039	0.0096				
* VI Dummy	(0.0373)	(0.0378)				
VI Competitors			-0.0445	-0.0424		
* VI Dummy			(0.0298)	(0.0307)		
Independent Competitors			0.1485	0.1598		
* VI Dummy			(0.1266)	(0.8178)		
Crude Oil Price	0.8225***	0.8194***	0.8209***	0.8178***	0.8237***	0.8208***
Current Day	(0.0641)	(0.0648)	(0.0639)	(0.0647)	(0.0636)	(0.0642)
Crude Oil Price	-3.0474***	-3.0470***	-3.0468***	-3.0464***	-3.0475***	-3.0473***
Past Calendar Month	(0.0848)	(0.0842)	(0.0849)	(0.0843)	(0.0851)	(0.0845)
Dummy for VI	Yes	No	Yes	No	Yes	No
Firm FE	No	Yes*	No	Yes*	No	Yes*
# Self-serve Pumps, Convenience Store (Small), Convenience Store (Medium), Convenience Store (Large), Car Wash	Yes*	Yes**	Yes**	Yes**	Yes**	Yes**
Distance from Highway, Population, Mean Household Income, Unemployment Rate, % Driving to Work	Yes***	Yes***	Yes***	Yes***	Yes***	Yes***

(Table 21 continues)

(Table 21 continued)

	(1)		(2)		(3)		(4)		(5)		(6)	
Day of Week FE	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***
Month FE	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***
City FE	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***	Yes	***
Intercept	172.69	***	173.00	***	171.78	***	172.22	***	171.68	***	172.06	***
	(5.6790)		(5.6771)		(5.4464)		(5.6878)		(5.6612)		(5.6560)	
Adjusted R^2	0.9390		0.9400		0.9393		0.9403		0.9392		0.9402	

Notes: The data are the same as in other tables. Column 1 and 2 focus on the effects of competitors in a 3 km radius interacted with a vertically integrated firm dummy. Columns 3 and 4 focus on local competitors by firm type (vertically integrated or independent) and interactions of these covariates with a vertical integrated dummy. Finally, columns 5 and 6 contain corresponding results of local competitors (within a 3 km radius) by brand. Bootstrapped standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level. Bootstrapped s.e. are based on Cameron et al. (2008).

Table 22: Sensitivity Analyses for Chapter 4

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	**Gas Price**	**Market Share**	**Market Share**	**Gas Price**	**Market Share**	**Market Share**
Competitors (in 3	-0.0266 *	-1.2562 ***		-0.2769 *	-1.2279 ***	
km radius)	(0.0140)	(0.0782)		(0.1470)	(0.3266)	
Competitors			-3.0458 ***			-2.5154
of Same Brand			(0.6681)			(1.9759)
VI Competitors			-1.0373 ***			-1.5898 ***
of Different			(0.1750)			(0.3607)
Brands						
Independent			0.1750			-0.4771 **
Competitors			(0.5154)			(0.2155)
of Different						
Brands						
Herfindahl	3.28E-05	0.0068 ***	0.0076 ***			
Hirschman	(7.46E-05)	(0.0008)	(0.0010)			
Index						
Crude Oil Price	0.5247 ***	-0.0074	0.0282	0.6661 ***	0.0512	0.0447
Current Day	(0.0610)	(0.0613)	(0.0647)	(0.0402)	(0.0433)	(0.0414)
Crude Oil Price	-2.2738 ***	0.147	0.2079	-2.2838 ***	-0.0267	-0.0218
Past Month	(0.1401)	(0.1313)	(0.1429)	(0.1039)	(0.1211)	(0.1144)
Wholesale Gas Price	0.2533 ***	0.0287	0.0690	0.3307 ***	0.0112	0.0168
Current Week	(0.0241)	(0.0539)	(0.0435)	(0.0197)	(0.0181)	(0.0199)
Wholesale Gas Price	0.292 ***	-0.0508	-0.0948	0.2575 ***	-0.0142	-0.0202
Past Week	(0.0381)	(0.0656)	(0.0632)	(0.0355)	(0.0224)	(0.0214)
Dummy for Vertically Integrated firm, Number of Self-serve Pumps, Convenience Store (Small), Convenience Store (Medium), Convenience Store (Large), Car Wash	Yes	Yes ***	Yes ***	No	No	No

(Table 22 continues)

(Table 22 continued)

	(1)		(2)		(3)		(4)		(5)		(6)	
Distance from Highway, Population 10k, Mean Household Income 1k , Unemployment Rate %, % Driving to Work	Yes	**	Yes	**	Yes		No		No		No	
Station FE	No		No		No		Yes	***	Yes	**	Yes	**
Day of Week FE	Yes	***	Yes	***	Yes	**	Yes	***	Yes	**	Yes	**
Month FE	Yes	***	Yes		Yes		Yes	***	Yes		Yes	
City FE	Yes	***	Yes	***	Yes	***	No		No		No	
Intercept	126.4233	***	2.4460		-16.398		123.70		21.4442		21.523	*
	(10.6521)		(7.4882)		(11.013)		(7.4085)		(13.4686)		(12.117)	
Adjusted R^2	0.9553		0.6633		0.6918		0.9597		0.9837		0.9839	

Notes: The data are for stations in 5 Canadian cities: Calgary, Regina, Saskatoon, Toronto and Winnipeg. The data were collected for: January, March, and May for Calgary, Saskatoon, and Regina; December, February, and April for Winnipeg; and for each month from January to May for Toronto. Column 1, 2, and 3 focus on the effects of competitors in a 3 km radius on gas prices and station market shares employing a Herfindahl Hirschman Index and current and one week lagged wholesale prices. Columns 4, 5, and 6 investigate the effects of the number of local competitors with station specific fixed effects and current and lagged wholesale prices. Bootstrapped standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5% level and *** denotes significance at the 1% level. Bootstrapped s.e. are based on Cameron et al. (2008).

Table 23: OLS Estimates – Distance on Station Market Share

	(1)	(2)	(3)	(4)
Distance to Closest	7.0409***	6.9919***	9.3847***	9.2735***
Competitor	(1.729)	(1.732)	(1.5701)	(1.601)
Distance to Closest	4.2014**	4.0307**	4.4513**	4.3225**
Competitor x Same Brand	(1.919)	(1.8599)	(2.0783)	(2.0651)
# Competitors within 3km	-1.7645***	-1.7421***		
	(0.103)	(0.098)		
Crude Oil Price	-0.1145	-0.1138	-0.3262***	-0.3204***
Current Day	(0.089)	(0.085)	(0.0865)	(0.0812)
Crude Oil Price	0.0653	0.0729	0.1271	0.1405
Past Calendar Month	(0.177)	(0.1762)	(0.181)	(0.1791)
Dummy for VI	Yes	No	Yes	No
Firm FE	No	Yes*	No	Yes*
# Self-serve Pumps, Dummies for Convenience Store Size, Car Wash	Yes**	Yes***	Yes***	Yes***
Distance from Highway, Population, Mean Household Income, Unemployment Rate, % Driving to Work	Yes**	Yes***	Yes***	Yes***
Day of Week FE	Yes	Yes	Yes**	Yes***
Month FE	Yes	Yes	Yes***	Yes***
City FE	Yes	Yes	Yes**	Yes***
Intercept	23.5808***	24.4964***	20.0303**	20.8512**
	(9.0839)	(8.3351)	(9.7627)	(8.7263)
N	3327	3327	3327	3327
Adjusted R^2	0.5650	0.5881	0.4468	0.4739

Notes: The data are station specific from 5 Canadian cities: Calgary, Regina, Saskatoon, Toronto and Winnipeg, and collected for: January, March, and May for Calgary, Regina, Saskatoon; December, February and April for Winnipeg; and for each month from January to May for Toronto. Columns 1 and 2 include distance to closest competitor variables and number of competitors variable, while columns 3 and 4 include only distance to closest competitor variables. Bootstrapped standard errors are clustered by brand. * denotes significance at the 10% level, ** denotes significance at the 5%

level and *** denotes significance at the 1% level. Bootstrapped s.e. are based on Cameron et al. (2008).

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