

Price Linkages in the Canadian Natural Gas Market: A Cointegration Approach

by

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I. INTRODUCTION

In Canada, natural gas accounts for more than 42% of total primary energy use, with 63.6 billion cubic meters consumed domestically in 1995, compared to 49 billion cubic meters in 1986 (National Energy Board, 1996, p. 27). Natural gas exports have experienced an even larger increase in volume, from 21 billion cubic meters in 1986 to as much as 78 billion in 1995. The Western Canada Sedimentary Basin (WCSB) represents the country's single most important natural gas source. This basin, covering over 1.5 million square kilometers and reaching a maximum depth of over 6.5 kilometers,¹ extends over most of Alberta, Saskatchewan, British Columbia, and parts of the Northwest Territories (figure 1) and supplies 94% of the natural gas consumed in Ontario (Ontario Energy Board, 1993, p. 7). This gas is transported to Ontario by TransCanada PipeLines, which is the main interprovincial gas pipeline in Canada, linking western Canadian gas producers with eastern Canadian and U.S. consumers (figure 2). Out of a total network of over 273,000 kilometers of pipelines in Canada, TransCanada PipeLines is considered one of the world's largest gas transportation companies, with over 13,500 kilometers of gas pipelines in Canada and the United States. The focus of this paper will be on the natural gas produced in Alberta and then transported along the TransCanada system to Ontario, where it is picked up by local distribution companies, which in turn deliver the gas to final customers (or end-users).

In the mid-1980s, government policy initiatives and regulatory actions, both in Canada and in the United States, changed the structure of natural gas markets in North America, by bringing in price deregulation, the unbundling of pipeline services, and by fostering a

¹ The Canadian Association of Petroleum Producers.

competitive market through equal and open access to pipeline transmission services. The deregulation process in Canada finds its source in the October 1985 *Agreement on Natural Gas Markets and Prices*, between the federal government and Canada's three western natural gas producing provinces of Alberta, British Columbia, and Saskatchewan. Prior to that agreement, the structure of the industry was simple but confining (Figure 3), where gas producers, both large and small, explored the country, developed and produced the gas, and for the most part, sold the gas to interprovincial pipeline companies under long-term contractual arrangements (usually 25 years), at prices regulated by the federal government.² In turn, the pipeline companies would transport the gas across the country and then sell it to provincially franchised monopolies, called local distribution companies (LDCs), at prices also regulated by the federal government. The LDCs, in turn, sold the gas to end users in Ontario at prices regulated by the Ontario Energy Board.

After deregulation however, pipelines, which once functioned as both sellers and transporters of gas, became primarily transporters, allowing producers, distributors, and marketers to play a larger role in supplying natural gas to end-users. Distributors, while still regulated in some form or another by their provincial governments, were given increased flexibility to be more responsive to the needs of their large-volume customers, allowing them to select the most effective and efficient mix of supply, transportation, storage, backup, and other services. At the producer end, deregulation has forced producers to cope with a lower price environment, and that caused the producing sector to expand sales volumes in order to maintain

² After the OPEC oil shock of 1973-74, exports of Canadian gas were priced to match more closely the energy-equivalent value of world oil prices.

cash flow, aggressively cut costs, and improve gas inventory management.³

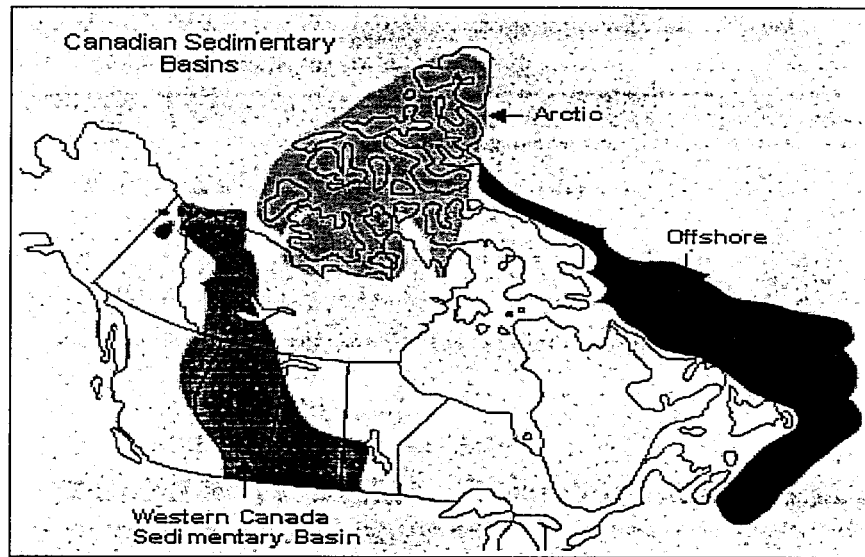


Figure 1 Canadian Sedimentary Basins

This paper will focus on the price linkages of natural gas between the largest producing province, Alberta, and the second largest consuming province, Ontario,⁴ as well as on the price linkages within Ontario's three market segments, namely, the residential, commercial, and industrial sectors. The premise of this study is that, after the *Gas Agreement* of 1985, the market shifted from a tightly regulated monopoly to a competitive market structure, where prices were no longer set by regulatory bodies, but were determined by the supply and demand for natural gas. Many studies have concluded that under these new market conditions there has been increasing evidence of market cointegration among the different segments of the natural gas market in North America. In particular, there is evidence that natural gas prices in different regions behave as if driven by the same market fundamentals. In this paper, this hypothesis will

³ National Energy Board (1996).

be tested for Canadian natural gas prices sold within Canada. In particular, the paper will test the natural gas prices at Empress, which are typically used to represent the Alberta border price,⁵ with the prices of natural gas in the three Ontario market segments.

The paper will follow the methodology used by Doane and Spulber (1994), in order to investigate the existence of a link between natural gas prices at the two ends of the distribution network by testing for price linkages between Alberta's producing sector and Ontario's consuming sector. Furthermore, the paper will test for price linkages within Ontario's three market segments, in order to quantify a relationship between the residential, commercial, and industrial prices, in terms of a market leader.

This paper will start in section II by discussing the structure of the natural gas industry in Canada, both before and after deregulation, with special emphasis on the national policy changes and the complementary policy actions in Alberta and Ontario. In section III, the paper will introduce and discuss the three sectors of the Ontario consumer market, namely the residential, commercial, and industrial sectors. Section IV will discuss previous contributions to the subject of natural gas deregulation, and review the various statistical methods that have been applied in the evaluation of market linkages in the natural gas industry in North America. Section V introduces the data used in this analysis and performs stationarity tests using the augmented Dickey-Fuller test. After that, section VI performs the empirical analysis on the data, and tests the price series for cointegration between Alberta's border prices and Ontario's consumer prices, and among the three Ontario market segments, and then reports the results. These results are then

⁴ Ontario is second only to Alberta in terms of provincial natural gas consumption.

⁵ The price data for Empress cover all spot contracts negotiated during a given month that call for delivery during the following month.

discussed and conclusions are drawn in section VII.

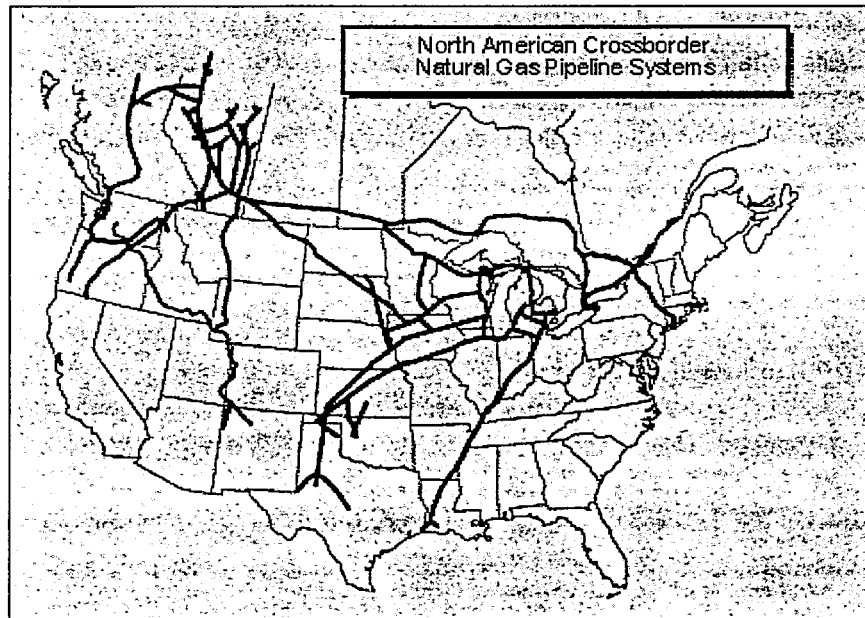


Figure 2 Natural Gas Pipeline Network

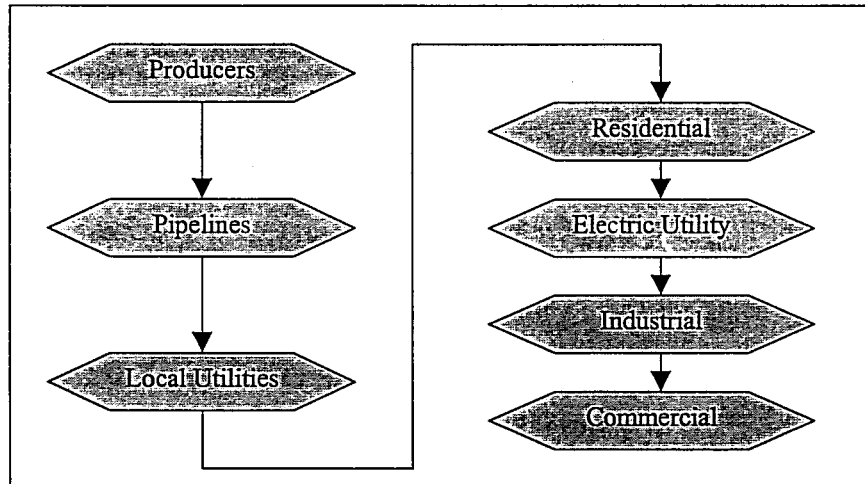


Figure 3 The Structure of the Gas Industry Prior to Deregulation

II. THE DEREGULATION FRAMEWORK

The deregulation of the commodity market for natural gas began in the late 1970s with a series of policy changes in Canada and the United States. These policies included price deregulation, the unbundling of pipeline services, and ensuring open and equal access to pipeline transmission capacity.

For many years, prior to 1985, the price of the Alberta natural gas sold to other provinces was determined by agreements between the federal government and the Alberta government. Pipeline companies had to buy gas under long-term contracts from producers, which delivered the gas to the pipeline company's inlet, and from there transported the gas to its downstream end-user market and sold it as bundled packages at the city gate.⁶ At the city gate,⁷ local distribution companies picked up the gas and distributed it locally.

This system of bundling gas sales services, together with the generous take-or-pay provisions in gas supply contracts, where the purchaser agreed to pay for a specified volume of gas during a period whether or not the contract deliveries are taken, led to an excess production capacity in the producing sector. In addition, most end-users purchased gas directly from LDCs at a fixed price per unit of gas, which would have included the actual field price of gas, transportation and storage charges, and residual charges or markups by LDCs. An important reason behind the tight price regulation of natural gas in Canada was that regulators did not want producers and/or pipelines to vary price in order to affect demand.

In 1985, however, two major federal-provincial agreements, the *Western Accord* and the

⁶ Such pipeline companies were known as merchant pipelines because they sold both gas and transportation.

⁷ The city gate is the delivery point or the point of intersection between a gas transmission pipeline and a local distribution system.

Agreement on Natural Gas Markets and Prices, initiated the transformation of the market for natural gas in Canada,. In March, as part of the *Western Accord*, the federal government signaled its decision to exercise less price regulation over natural gas. On 31 October 1985, the governments of Canada, Alberta, British Columbia, and Saskatchewan announced the *Agreement on Natural Gas Markets and Prices*, which was intended to create conditions within the regulatory environment which could foster a market-responsive pricing system in the natural gas industry. This agreement initiated the transformation toward a competitive Canadian natural gas market by deregulating field prices of natural gas over a one-year transition period and allowing end-users,⁸ who were significantly regulated, to negotiate prices and purchase gas directly from producers for the first time.

These changes in the natural gas market were favored by the province of Ontario on the basis that lower gas supply prices would benefit Ontario's economy. On 23 March 1986, the Ontario Energy Board (OEB) defined the core market as those volumes that are sold by the LDCs. The OEB also stated that anyone who wished to buy gas directly from producers could now do so. However, the OEB found that the supply of gas to the core market should be protected by the LDCs, which should make any contractual arrangements necessary to ensure that gas would be available. The OEB further stated that the responsibility for security of supply to the non-core market rested with the direct purchasers themselves.

In order to encourage market-responsive pricing for natural gas, the OEB identified several conditions that must be met. First, consumers must be free to choose their supplier. Second, transportation services on TransCanada PipeLines and LDC systems had to be provided

⁸ End-users are customers who actually consume or burn natural gas, as opposed to ones who sell or resell it.

to all gas consumers on equal terms, and finally, buyers must have access to sufficient information concerning market prices of natural gas. In order to meet these conditions, the OEB directed the utilities to segregate the cost of gas from the cost of transportation and develop cost studies on transportation, storage and load-balancing services. In order to facilitate access to transportation services, the OEB found that the separation of marketing and transportation functions was necessary, as this would improve the competitive environment by ensuring that LDCs market gas on equal terms with brokers and producers (OEB, Annual Report, 1986). For that reason the OEB ordered the LDCs to file for new end-user prices (also known as rate proposals) during the summer of 1987 so that final implementations of the contract carriage rate could take place in the fall of 1987.⁹ Furthermore, the OEB proclaimed that natural gas in Ontario had to be sold under a Board-approved rate order, and that gas distributors would be required by law to submit price (or rate) proposals to the Board for review and approval. These rates varied however between the different classes of residential, commercial, and industrial sectors.

In the fall of 1987, the OEB conducted public hearings that dealt with the issues of customer classification, cost allocation, and unbundled rate design for the three major utilities in Ontario.¹⁰ As a result the OEB issued its decision in May 1988 approving the LDCs unbundled transportation rates and services, which had only been available in a bundled all-inclusive form prior to that decision. In setting these rates for the three different classes of customers, the OEB's objective was to reflect the costs imposed on the system by the varying demands of the different classes. Residential demand for natural gas as a heating fuel, for example, changes according to

⁹ Contract carriage is a transportation service provided for the transport of gas not owned by the pipeline company.

the weather and time of day. As a result it costs more on a per unit basis to provide services to residential customers than to industrial customers, which use relatively large amounts of gas at a more stable rate. In proceeding this way, the OEB tried to strike a balance between the prices to be paid by customers and the rate of return that shareholders of the utilities are allowed to earn.

As a result of these changes, the Canadian natural gas market was transformed into a competitive market that was market-driven rather than regulation-driven. End-users now had the option of entering into gas purchase agreements with any supplier directly or through various brokerage firms, which became known as ABMs.¹¹ The method of choice depended on the size of the end-user's operation; for example most large end-users opted for directly purchasing gas from producers, while smaller end-users utilized the services of ABMs. However, Ontario allowed these ABMs to market gas directly to the core customers provided that they met certain conditions.¹² In addition, LDCs offered two new different types of direct gas purchase services to their customers known as the T-service and the buy/sell mechanism.¹³

Each of the three major gas utilities now sells and transports gas in a franchised area of the province of Ontario, and competition exists in the sales of energy. Buyers may purchase gas directly from producers or from local distributors, or they may change to other sources of energy altogether. Prior to mid-1986 direct sales of natural gas did not exist in Ontario, and as a result of deregulation, within the three Ontario LDC franchise areas, direct purchases jumped to 34% of

¹⁰ At that time, the three major gas utilities in Ontario were Consumers Gas, Union Gas, and Inter-City Gas (ICG).

¹¹ ABMs refer to the newly created agent/broker/marketer firms whose business is to buy and sell gas on the market.

¹² The OEB announced the Minimum Conditions of Supply in 1992, but revoked them in 1993.

¹³ *T-Service* is a gas transportation service offered by a pipeline company or distributor to transport gas owned by others, and the *buy/sell agreement* is an agreement whereby an end-user purchases gas from a producer and then sells it to an LDC who commingles that gas with other supplies. The end-user then buys gas from the local utility in the usual manner except that the price paid to the producer and the price received from the local utility minus any transportation costs accrues to the end-user.

total residential gas sales volumes, and to as much as 75% of total commercial gas sales. Overall, the direct/total sales ratio in Ontario was at 64% in 1995 (National Energy Board, 1996).

The reason for studying Ontario in this paper is that it relies heavily on natural gas as an energy source and feedstock. Natural gas is the major fuel for all sectors of the economy except transportation, and it is the primary fuel used in heating space and water in the province. Ontario's demand for natural gas accounts for approximately 40% of the total demand for Canadian natural gas, and natural gas provides approximately 32% of the energy consumed in Ontario, with 94% of the gas consumed in the province obtained from the western provinces by way of the TransCanada PipeLines and associated systems.¹⁴

Since the mid-1980s, deregulation has brought a number of changes to the market. An important outcome of deregulation was the increased transparency in gas pricing. The commodity cost of gas from western Canada accounts for one-third of the typical residential sales rate, and the balance of the rate covers transportation from the west to the distributor and the operation costs of the LDC. Wholesale gas prices are largely no longer set by governments; instead competition exists, and prices are driven by gas market fundamentals. Now, buyers can purchase gas directly from producers and make transportation arrangements via negotiated contracts with TransCanada PipeLines and LDCs. Even small gas users often participate in direct purchase arrangements as part of a large purchasing group. This purchasing group would in turn organize the negotiations with producers or marketers for gas supply on behalf of all participants, and then make the necessary transportation arrangements.

Unlike Ontario, Alberta was the last province to allow direct sales to core customers. The

¹⁴ Ontario Energy Board, Annual Report, 1993-1994.

new regulations regarding these types of transactions came into effect in 1995, where core customers were given the option of either staying with their local LDC or using another supplier. In addition, in early 1996 the Alberta Energy and Utilities Board approved the two types of services that LDCs in Ontario had been offering for a long time to their core market customers.¹⁵ However, because Alberta is mainly a producing province, the purchasing practices in that province did not change much after deregulation. This is due to the fact that many of the large LDCs in Alberta were already purchasing gas directly from producers and not from pipeline companies such as TransCanada PipeLines, as was the case in Ontario.

The natural gas market mechanisms have been profoundly changed since deregulation. Spot markets have emerged in Canada, with spot prices published daily, and short-term contracts replacing long-term contracts. In response to these changes, several small-sized marketing agencies were created at first. However, as the market for natural gas became more efficient and access to information was greatly improved through published resources and electronic gas trading bulletin boards, these small marketing firms faced a very competitive business environment that forced many of them to merge and create a number of mega-marketers.

In addition, as a result of the *Gas Agreement* of October 1985, end-users were given the option of utilizing transportation services along the gas transmission network (also referred to as open access), gas sales practices changed fundamentally all over Canada, and the degree of change depended on the extent of accommodation of the different provincial regulatory bodies. Since deregulation, the natural gas market in Canada has shifted from long-term to short-term based transactions. This shift towards short-term contracts was facilitated by the development of

¹⁵ These services are the *T-Service* and the *Buy/Sell Arrangement*, see footnote 13 above.

a number of spot markets¹⁶ for gas in the late 1980s, some of which eventually turned into market hubs.¹⁷ The influence of spot markets continued to increase throughout the early 1990s, and by 1995, pricing of most short-term and long-term sales contracts was determined according to indices of monthly spot prices in the relevant market regions. Furthermore, due to the efficiency of these spot markets, short-term supply/demand imbalances were able to be corrected quickly. As a result of the success of spot markets, futures contracts were established in many markets, which helped improve the transparency of gas prices, whereby the relative value of gas at different points in time can be easily determined.

In conclusion, the Canadian natural gas market has experienced significant changes since the mid-1980s. Government control of pricing and distribution was replaced gradually by open-market mechanisms, which included open access to transportation facilities and price deregulation. As a result of these changes, end-users were given the opportunity to choose their suppliers and to contract transportation services. Furthermore, deregulation of prices and the forces of open-market operations resulted in a decrease in natural gas prices almost immediately following deregulation. Now, the market is more short-term in nature, with spot markets and futures markets operating at different hubs across North America.

¹⁶ A spot market is a commodity transaction market in which the transaction commencement is near term, such as 10 days, and the contract duration is relatively short, such as 30 days.

¹⁷ A market hub is a geographical location where large numbers of buyers and sellers trade gas and where gas can be physically delivered.

III. THE ONTARIO CONSUMER MARKET

The Ontario consumer market is made up of the residential, commercial, and industrial sectors. These sectors have very different characteristics, which determine their nature and the price behavior that is associated with them. In this section, I will discuss the market forces that influence these three market sectors and investigate the relevance of the different pricing mechanisms that are associated with them.

Up until the mid-1990s, the industrial market in Ontario had been the largest end-user market, and represented the largest source of growth and market stability for natural gas. The industrial sector is made up of the large manufacturing sector, which includes industries such as electricity generation, pulp and paper, iron and steel processing, and petroleum refining. Industrial energy consumption is made up of two components: fuel and power consumption,¹⁸ and feedstock energy consumption in the production of petrochemicals. Both of these components are tied to industrial production growth, and are functions of short and long-term trends in relative energy prices. Natural gas serves the majority of industrial process-heat applications, which are made up of thousands of furnaces, ovens, reactors, and other types of heating equipment.

Energy prices, and in particular natural gas prices, are very important drivers for the industrial demand for natural gas. This is due to the fact that real natural gas prices and residual fuel oil prices follow each other closely, as many industrial customers have the ability to switch between natural gas and residual oil relatively quickly and easily. The deregulation of natural gas prices and the advent of a natural gas transportation market in the mid-1980s have moved

industrial gas purchases away from direct sales by LDCs and towards a producer-consumer market environment, where industrial consumers engage in market transactions in order to find the most efficient and cost effective contractual arrangements. While competition does not always result in an increased market share, the move to a more competitive environment is considered favorable to maintaining and/or expanding the use of natural gas by the industrial sector.

Natural gas also plays an important role in the development of the commercial sector. This sector has the lowest share of the Ontario market for natural gas, and is made up of large commercial establishments such as shopping centers and show rooms, in addition to schools and hospitals. Natural gas has the largest market share for commercial space and water heating, among other uses. While it was the dominant fuel in the commercial sector through the early 1970s, the OPEC oil-price spike and gas deliverability problems caused the commercial sector gas demand to decline sharply, to the benefit of electricity, between the early 1970s and the mid-1980s.¹⁹ However, in recent years, natural gas has begun to recapture some of its lost market share. Energy prices represent an important criterion in the choice of fuel to meet the energy services requirements for the commercial sector. However, short-term changes in gas prices do not have a significant impact on commercial energy demand, unlike the industrial demand, due to the expenses associated with fuel switching. Furthermore, most commercial users do not have the energy-using equipment that would allow them to switch fuels easily.

¹⁸ Fuel and power consumption includes the raising of steam and the onsite generation of electricity.

¹⁹ The reason for the decline in the demand for natural gas was that the regulated gas prices were tied to oil prices when the OPEC oil-spike took place in the early 1970s.

Ontario's residential sector is made up of hundreds of thousands of households that rely on natural gas for space and water heating. The demand for natural gas in Ontario's residential sector has been on the increase since the mid-1980s. This is attributed to the decline in natural gas prices due to deregulation and open access, and to the marketing strategies of LDCs that encouraged residential consumers to switch from electric and oil heating equipment to new and more energy efficient natural gas equipment. The residential market for natural gas, like the commercial market, is not affected by short-term changes in gas prices because of the expenses involved in switching to alternative energy sources. Figure 4 shows the average annual amounts of natural gas sold in Ontario by sector from 1980 to 1996 in Terajoules. It is clear from the graph that the residential sector share of Ontario's natural gas market has been increasing since the mid-1980s, and that it now slightly outweighs the industrial sector.

Currently in Ontario, LDCs, such as Union Gas and Consumers Gas, are required to submit rate proposals to the Ontario Energy Board for approval (OEB, 1993, p.9). These rates vary among the three end-user market segments, and are evaluated by the OEB according to specific criteria. The OEB's criteria are first to determine the appropriate level of expenses that are incurred by the LDC in the process of delivering gas, and then determine the costs imposed on the system due to the varying demands of the different classes of customers. The objective of the OEB, in determining these rates, is to reflect the differences in per-unit costs.

Therefore, when studying market linkages among the three end-user market segments in Ontario, the paper will analyze these price differentials in order to establish a relationship between these markets in terms of market price leading and following. However, from figure 4,

one can see that there has been a reversal of the relative rankings of the industrial and the residential markets after 1995, where the Ontario residential market share of natural gas became larger than the industrial sector. Furthermore, because the industrial market is highly sensitive to changes in natural gas prices, and to changes in other energy prices for that matter, it would seem natural to assume that it is a price leader. However, Figure 4 shows that the average annual sales of natural gas in the residential market have exceeded those of the industrial market since 1995, and this could pose a problem in the analysis, since the assumption was that industrial demand is more price sensitive, because of the fuel-switching capability, and because large industrial buyers have more access of supply available to them, and hence the industrial sector would seem to be a natural market leader.

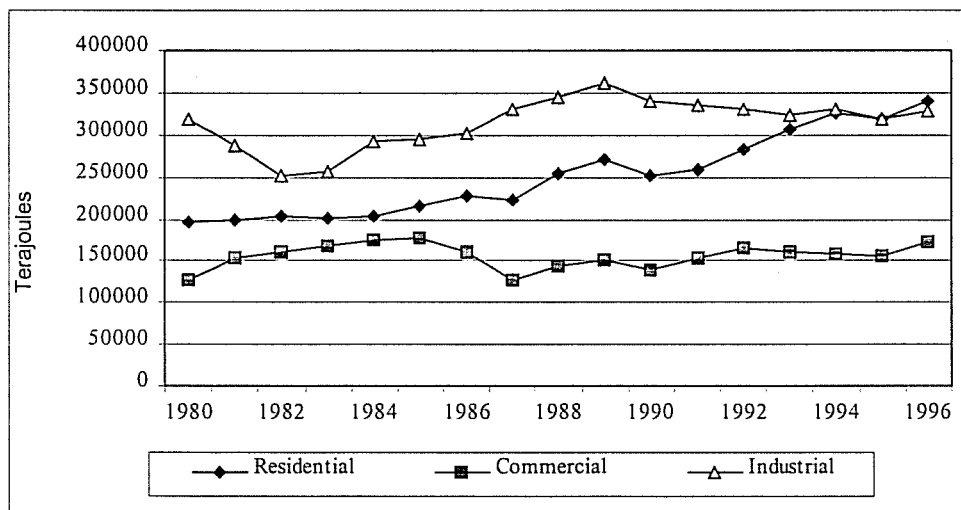


Figure 4 Sales of Natural Gas in Ontario (source: CANSIM, Quarterly S&D)

In addition, the following sections will study the degree of price integration and the relationship between the Alberta border price for natural gas and each of the three Ontario end-

user prices. This analysis would provide insight into the degree to which the Ontario core market has benefited from greater competition, and whether prices are moving together. If they are, then there will be a cointegrating relationship among the price series, which could be attributed to deregulation and open access, and if they are not then we could investigate the possible negative effects caused by increases in transportation and residual charges charged by pipeline companies and LDCs in order to compensate for the increase in demand due to deregulation, and in order to pay for the expansion of the transmission network.

IV. PREVIOUS CONTRIBUTIONS

Even though many studies have dealt with the subject of price convergence and market cointegration for natural gas in North America, most of these studies have focused on the U.S. natural gas market or have used U.S. data in their analyses. Nonetheless, both the U.S. and Canadian markets are very similar in many aspects. Both markets shared the same regulatory framework prior to deregulation, with market deregulation in Canada taking place in the mid-1980s, while deregulation in the United States taking place in the late 1970s, deregulation resulted in similar competitive market structures in both countries, where prices are determined by the forces of supply and demand. Furthermore, both the U.S. and Canadian natural gas markets share the distinction of having a mostly producing sector in the west, and a mostly consuming sector in the east, which makes the analysis of cointegration between Ontario's end-user market and Alberta's producer market comparable to U.S. analysis. Furthermore, both the Canadian and American markets for natural gas have the same market instruments such as spot and futures markets.

Therefore, in order to establish a hypothesis about price relationships in the Canadian natural gas market, a review of earlier contributions to the subject is useful in order to evaluate the various methods and techniques of analysis that have been used in evaluating the effects of open access and price deregulation on the American market. In addition, the paper will attempt to evaluate their results and make the connection to the Canadian natural gas market.

The major argument behind the regulation of such systems as natural gas pipelines is that these exhibit the features of a natural monopoly, especially the existence of significant

economies of scale. The construction of transmission system was strongly influenced by the theoretical principles underlying natural monopolies, and were regulated as theory prescribes (De Vany and Walls, 1995a). In recent years, however, a counter argument has arisen and points to the failure of the regulators to recognize pipelines as being only a part of a larger network, and to the misrepresentation of how coordination can be achieved in a complex system. De Vany and Walls point out that pipelines are not natural monopolies, and that they can be organized competitively within an interconnected pipeline system framework by making transmission an asset that can be traded in a market that is open to all to participate in.

This brings us to the heart of the matter, which as noted earlier is the subject under investigation in this paper, and that is the effects of deregulation and open access on the end-user markets, and how these prices are linked with producing areas (Walls, 1994). The argument is that, if open access is functioning well at the local level, then the marginal value of gas should be equalized across city markets and field markets if there is an efficient allocation of gas between production and city markets. Hence a question that this paper will try to answer is: how well do gas prices in the Ontario market track field prices in Alberta? However, it is unclear yet if the benefits of open access are extended to users behind city gates. This is because many LDC transmission lines are still heavily regulated by provincial authorities, and these regulations differ from one provincial jurisdiction to another, which makes prices artificially different in different markets. Walls (1994) concluded that city markets which have adopted some form of open access at the local level are more integrated with field markets. From this perspective, we might expect Ontario markets to have good results in terms of integration compared to the rest of Canada,

because Ontario was the second province to adopt and support deregulation, and move forward ahead of the other provinces towards a more competitive market for natural gas.²⁰ Walls (1994) used a sample of daily spot prices in the United States at 20 nodes located within 6 geographical areas and connected by 11 major interstate pipelines, from 1989 to 1990. He found that the majority of market pairs examined showed signs of integration.

In general, competitive prices tend to move together, and the price differentials decline over time. Therefore, if we assume that the market for natural gas in Canada has become a competitive one, then we should be able to observe the above two properties in the relevant natural gas price series. These prices should move together within a band related to transportation costs in order to keep them from becoming large enough for arbitrage opportunities to emerge.

In order to see the impact of deregulation on the pipeline network, one could study the competitiveness of natural gas pricing at different networks. Evidence from the United States shows that from July 1987 to June 1988, competitive pricing among six pipeline networks in the United States did not exist, and a year later from July 1988 to June 1989, prices in 5 of the 6 networks had become strongly competitive. Later on from July 1989 to June 1990, all pipeline networks showed strong competitive prices, and these prices reflected the same information with no opportunity for arbitrage (De Vany and Walls, 1995b).

Since deregulation, the structure of the natural gas market has changed significantly in many aspects. Deregulation has focused on, among other things, the transportation side of the

²⁰ Ontario was the second province after British Columbia to allow direct sales to core customers.

market, where its prime directive was to separate the sales and transportation services, and to guarantee open access for all shippers. As a result, customers entered the market to buy gas directly from producers, which resulted in the development of national competitive market for natural gas.

In order to test whether the market for natural gas has indeed become national in scope, regional spot markets could be tested for integration since deregulation using various methods such as price correlation, Granger causality, and cointegration tests (Doane and Spulber, 1994). For example, competition as a result of open access should, theoretically, result in a more integrated markets for natural gas. Assuming also for the sake of argument, constant gas transportation costs, one should get perfectly correlated field prices. The reason for that is that if there is a greater positive price correlation among the prices for the same type of product, then there is indication that these products are in the same geographical area. Under this assumption, one could test for price correlation and cointegration among field prices.

These three techniques are used in order to highlight different aspects of the unification of the regional markets into a national market for gas. A greater positive price correlation between price series over time implies a greater likelihood that the products are in the same geographical market. In other words, using correlation techniques, one could test the hypothesis that the market for natural gas has become national in scope, with different regions becoming more integrated, as a result of open access. The Granger causality test on the other hand, can help explain whether the geographic scope of the market was broadened after open access, by testing whether there is instantaneous Granger causality between markets. Finally, cointegration

techniques help determine the extent to which economic forces tend to keep price series moving together. Using the definition of cointegration,²¹ one could test price series for more evidence of broadening in the scope of the natural gas market after open access.

The fact that there has been a reduction in the volume of purchase contracts between pipelines and producers, and selling between pipelines and customers suggests that open access has merged or integrated regional markets into a national competitive market. Furthermore, if the different spot markets along the transmission network are operating competitively, then as a result, these competitive prices at different points in the network should be free of arbitrage opportunities (De Vany and Walls, 1993). In addition, if the prices are equalized up to the cost of transactions so that no profitable arbitrage opportunities remain, then these prices are considered to follow the law of one price (National Energy Board, 1995).²² Therefore one could test the theory of one price in order to assess the degree of connectivity between different markets. If the law of one price holds, then it is an indication of an increasing degree of integration among the different markets under study.

Using cointegration techniques, one could test for arbitrage-free pricing using time-varying series of daily spot prices of different market pairs within different geographical locations.²³ In their 1993 paper, De Vany and Walls concluded that 66% of the market pairs that they studied became more strongly integrated after deregulation, and that the degree of

²¹ Two or more variables are cointegrated if each is individually nonstationary, but there exists a linear combination of the variables that is stationary.

²² The law of one price as defined by Cournot and Marshall is the area within which the price of a good tends to uniformity, allowances being made for transportation costs.

²³ A market pair is here defined as two markets that are being tested for a price relationship between them.

integration became independent of the distance between the pairs, which is a characteristic of a national market.

However, one might have expected a higher degree of price convergence in the North American natural gas spot markets, and not only 66% of the market pairs exhibiting cointegration. This result shifted the focus towards an east-west split in natural gas field pricing (King and Cuc, 1996; NEB, 1996). Using a Time Varying Parameter Kalman Filter on natural gas spot price pairs, King and Cuc concluded that even though price convergence has increased since deregulation in the mid-1980s, there is a clear east-west split in natural gas prices, reflecting different market mechanisms that influence different regions. The NEB also concluded that there is such a split between eastern and western markets, with the Alberta market having stronger links with the Western United States. These results suggest that natural gas prices in the same region share stochastic trend components that are proportional to each other, which function as an error-correction mechanism, and hence produce cointegrated series within each region. However, other studies have found that natural gas prices within any region in North America, east or west, do not cointegrate (Serletis, 1997), and therefore because prices within each region are driven by different stochastic trends, the east-west split does not exist. This outcome could be the result of the failure of arbitrage to bring prices together, hence resulting in unexplained profit opportunities that cause the marginal value of natural gas to differ across locations by more than the transmission and transaction costs.

In another type of analysis, the pipeline deregulation aspects of natural gas markets was studied. Open access has transformed the transmission network from a closed, disconnected

system to a system of open access and connected pipelines. Under this new network structure, one could characterize the structure of prices at pipeline interconnections within the transmission network in order to determine the degree of integration (De Vany and Walls, 1994a). Under these assumptions, it is possible to model arbitrage over the natural gas pipeline network following pipeline deregulation, by estimating models of spot prices over the network and showing that the emergence, evolution and performance of natural gas spot markets are linked with the reorganization of natural gas pipelines brought about by open access. In this context, De Vany and Walls used Vector Auto-Regression models and Impulse Response analysis of 20 vertices for daily spot prices since July 1987 within 6 geographical areas, to prove that arbitrage opportunities were not fully exploited when the network had a low level of connectivity prior to deregulation. Within this sample, thirteen of the major interstate pipelines, which account for the majority of the gas flowing through the interstate pipelines, were represented. Then the vector autoregression model was used to examine arbitrage opportunities in order to determine if and how opening the pipeline network led to convergence in prices across locations and pipelines. The conclusion was that open access has opened not only individual links in the network, but promoted the emergence of a strongly interconnected network. Furthermore, after deregulation, price variations at a particular node were damped within a day at that node and within two days at other nodes. This result showed that the law of one price holds over the network, and when shocked, it is restored in less than two business days.

Another method to evaluate the effects of open access on the pipeline network is to develop a simple model of competition in the gas pipeline network by quantifying the properties

of the price series using the Dickey-Fuller Unit Root test, and then applying cointegration analysis to daily gas spot prices, to see if there is a relationship between different points along the network (Walls, 1994). Using multivariate cointegration techniques, Walls showed that within and between production markets there is a high degree of competition, and there is an efficient allocation of gas across the production markets. Furthermore, the daily spot price series from July 1990 to June 1991 for 20 field markets and 6 spot markets in 6 geographical regions, showed that 68% of the 120 market pairs did not show evidence of market integration, and even though production markets showed evidence of integration, it was less evident between production and city markets. In addition, city markets that have adopted some form of open access at the local level showed stronger evidence of integration with producing markets. This conclusion is very important in that it emphasizes the importance of further deregulation at the local level, and in the case of Canada at the provincial level.

In addition to evaluating the various natural gas markets on both ends, and analyzing the degree of network connectivity along the natural gas pipeline systems, it is also equally important to study and analyze the overall price behavior since deregulation, and the impacts of the domestic policies on the industry transformation and as a result on consumers. An important question that should be asked is whether gas markets institutions have been designed to avoid coordination failures. So far, evidence suggests that gas markets have rapidly emerged with the dissolution of regulatory barriers, and prices have converged and have become highly correlated (De Vany and Walls, 1994b). The evidence clearly shows that a national market for gas developed in four years following deregulation, and natural gas prices now exhibit a high degree

of positive correlation. Furthermore, they note that price spreads have become less volatile since deregulation, and argue that this provides additional evidence that regional markets have moved towards a single national market.

In Canada, however, the evidence seems to be less conclusive. Some linkages are found among producing provinces since deregulation (Plourde and Watkins, 1996). Cointegration tests across field prices, city gates, and end-user markets show some convergence; however, some of the results are puzzling. These disparities could be attributed to the evidence of preferential pricing practices within producing provinces. In addition to that, some markets seem to be diverging rather than converging, such as producer natural gas prices in Alberta and British Columbia. There is also evidence of production field linkages in Canadian natural gas markets, but very weak linkages in consumer markets. Overall, the markets for natural gas in North America have exhibited improved efficiency and flexibility due to the establishment of more market-oriented regulatory regimes, and the growth in market-responsive transportation services (NEB, 1995). Furthermore, the degree to which Alberta prices seem to have integrated with the rest of the North American markets was the result of the increased pipeline export capacity to the United States and the increased access given to the U.S. pipelines for Canadian gas, which caused the Alberta market to have the greatest degree of integration with the western U.S. markets. It is clear however, from the available empirical evidence, that natural gas markets have been successful in developing efficient institutions through self-organization rather than a handed-down approach. These markets succeeded because open access gave them scope to operate, and enabled new kinds of traders to join the market and in the process giving those

traders the means for trading over wide areas (De Vany and Walls, 1994c). As a result, according to De Vany and Walls, prices at widely separated points follow one another so closely that one can only conclude that they all must be in one market.

Deregulation and open access have benefited the energy market in North America in another way. Since gas prices are no longer tied to oil prices, the events of the mid-1980s have resulted in the development of a gas supply industry, where the supply of gas has become price elastic and thereby untied and insensitive to world oil prices (Sutherland, 1993). This benefit is realized in the enhanced security of the North American energy markets, in contrast to the European markets, where gas prices are tied to oil or even coal prices. Furthermore, Sutherland analyzed the prices and duration of natural gas contracts in the U.S. after deregulation, and came to the conclusion that the new market structure encouraged shorter-term contracts and spot purchases at market based prices, and that U.S. LDCs were able to obtain long-run reliable supplies of natural gas at those prevailing market prices.

Overall, most studies have concluded that deregulation has resulted in a more competitive market structure, where prices are correlated and track each other. However, there are some price differentials between producer markets and consumer markets, which could be attributed to the lesser extent to which deregulation has occurred within city markets. For that reason, it would be interesting to investigate the relationship between gas prices in Ontario and Alberta, and to examine the extent of their cointegration.

V. FRAMEWORK AND DATA ANALYSIS

As deregulation and open access came into effect in Canada in the mid-1980s, the fundamentals of the market for natural gas changed profoundly, as was mentioned in the previous discussion. Regional markets were expected to merge together into a national competitive market for natural gas, where the "law of one price" would prevail. In other words, when studying two markets for natural gas that have been deregulated, the difference in prices between the two markets should reflect transportation costs only, as other differences would be eliminated automatically by supply and demand activities or arbitrage, all of which determine the equilibrium upstream and downstream prices. Therefore, one would expect some kind of a relationship to emerge between these two distinct markets after deregulation, assuming of course that price distortions have decreased and that transportation and transaction costs have become less volatile.

Different types of data have been used in previous studies to analyze the degree to which market integration for natural gas has occurred across North America. A number of these studies have focused on long-term contracts for natural gas, while others have used spot prices at different regional markets. The fact that short-term contracts and real-time trading for natural gas have become widespread, and have replaced many long-term contracts between producers and pipeline companies since deregulation and open access, suggests that natural gas spot prices should be a good indicator of the degree of market integration. In this paper, we will attempt to examine the relationship between natural gas spot prices in the Alberta upstream market and gas prices in each of the three sectors of the Ontario downstream market.

The natural gas price data used in this study are divided into two main sets. The first set represents monthly averages of natural gas prices paid by residential, commercial and industrial

consumers in Ontario from January 1980 to December 1996, inclusive. These prices were obtained from the Statistics Canada database (CANSIM) and are measured in cents per cubic meter. The second set represents Alberta border natural gas prices, which were compiled from a number of sources²⁴, and covers the periods from January 1980 to October 1987, measured in dollars per gigajoule (\$/GJ), and from December 1988 to December 1996, measured in dollars per million Btu (\$/MMBtu),²⁵ all of which are in Canadian dollars.²⁶

These price sets represent two different types of markets in two different geographical locations, and the intuition behind using them is that Alberta, being the major natural gas producer in Canada, has the largest market share of natural gas sold in Ontario, which on the other hand, is the largest natural gas consumer in Canada. Therefore, through this interdependence we would expect a relationship to have emerged since deregulation between Alberta border prices and Ontario consumer prices.

In order to apply the testing procedures to the data, the measurement units had to be standardized into the basic metric, non-thermal, cents per cubic meter unit. For that, conversion factors, which vary from one year to another,²⁷ were used in order to convert the \$/GJ and \$/MMBtu into cents per cubic meter (cents/m³).

The Alberta border prices from January 1980 to October 1985 represent the regulated price of natural gas, and from November 1985 to October 1986 represent the price freeze that was put in place by the National Energy Board for the one year transitory period at 2.7804 \$/GJ. From November 1986 to October 1987, the border price was set at 2.57 \$/GJ by Alberta system

²⁴ Sources are: Woodside Research Ltd., and CAPP Statistical Handbook.

²⁵ Btu refers to British thermal units, a standard measure of energy content. In general, one Btu equals 1,054.615 Joules.

²⁶ The appendix lists all four sets of data: Ontario's residential, commercial, and industrial prices as well as Alberta's border prices, from January 1980 to December 1996.

²⁷ Conversion factors are provided in the Energy Statistics Handbook, published by Statistics Canada, on a yearly basis from 1978 to 1996.

gas producers and by the Province of Alberta.²⁸ The period from November 1987 to November 1988 is the missing link in this analysis, for it represents a chaotic transitory period, where private contracts were renegotiated, and prices were not easily traced. Since then, from December 1988 to the December 1996, the Canadian Association of Petroleum Producers has kept track of the Alberta border price at Empress, using a weighted average of all deals completed in the previous month for the month of delivery, and published in the CAPP²⁹ statistical handbook. These prices were also verified using the weekly average natural gas spot prices published by Oilweek.³⁰ Overall, the data sources for the Alberta border prices seem to be consistent in measurements as they all reflect the border price at Empress, which is a base measure for the Alberta upstream natural gas prices.

In order to analyze the series, they were first divided into two parts. The first, from January 1980 to October 1987, is referred to as the *regulated prices era*, and the second, from December 1988 to December 1996, is referred to as the *deregulated prices era*. The reason for this split is not arbitrary, but comes from the fact that the price series from November 1987 to November 1988 represents the crucial period when many gas contracts were renegotiated, and privately negotiated prices began to take effect. Furthermore, during this period, these prices are not publicly available for research purposes, and it is clear, however, that the structural break in the Alberta border prices took place during that period, as can be seen in figure 5.

For the purpose of consistency, the price series for the Ontario residential, commercial and industrial prices were split in the same manner for the statistical analysis. Figure 6 shows these three price series from January 1980 to December 1996.

²⁸ Murphy (undated, P. 9).

²⁹ CAPP is the Alberta-based Canadian Association of Petroleum Producers.

³⁰ Oilweek is a weekly publication based in Calgary, Alberta.

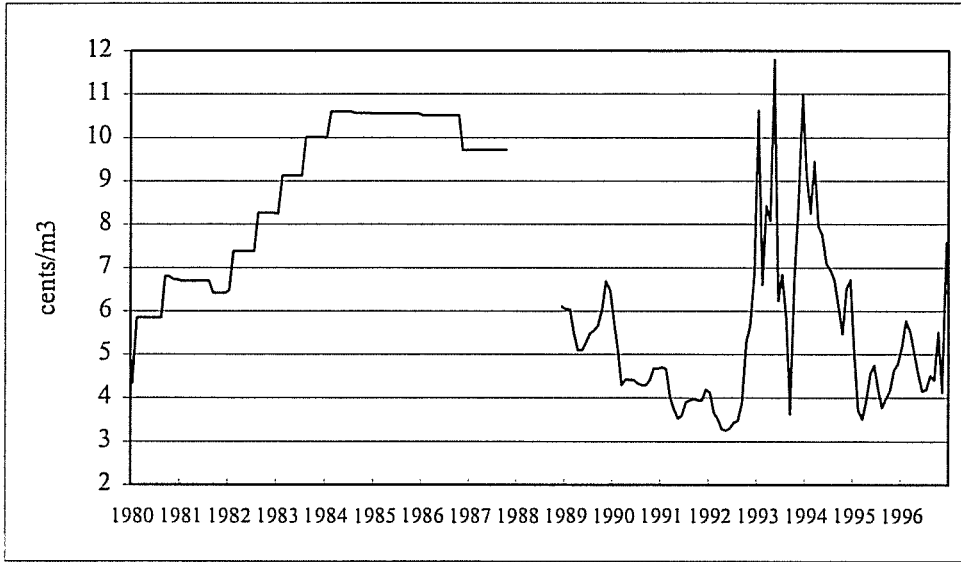


Figure 5 Alberta Natural Gas Prices

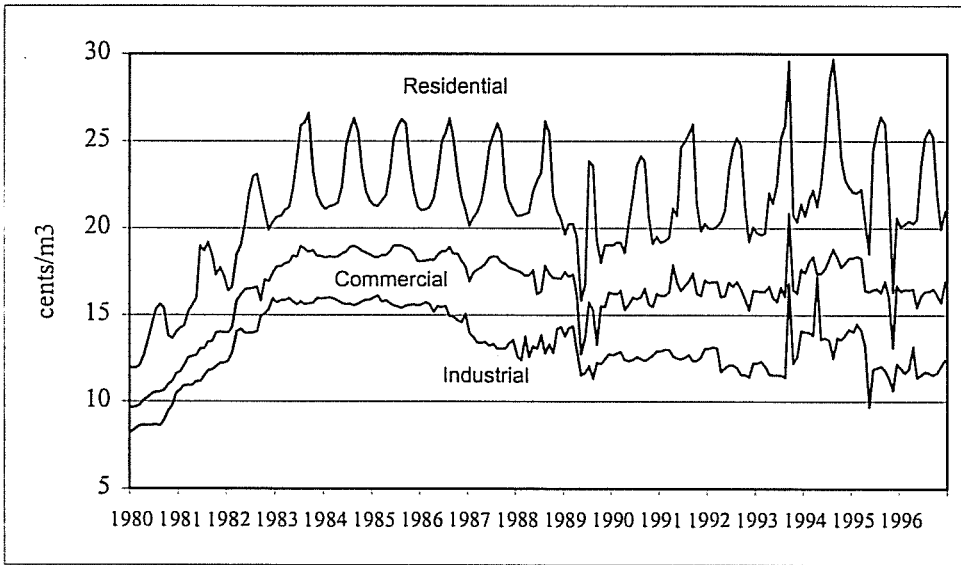


Figure 6 Ontario Residential, Commercial, and Industrial Gas Prices

Each of these price series was tested for nonstationarity using the augmented Dickey-Fuller (1979) test. This test consists of running a linear regression of the first difference of each of the price series ($\Delta p_t = p_t - p_{t-1}$) on the lagged price series (p_{t-1}) and lags of the first differences:

$$\Delta p_t = \alpha_0 + \alpha_1 p_{t-1} + \alpha_2 t + \sum_{i=1}^{\rho} \beta_i \Delta p_{t-i} + \mu_i$$

The value of ρ is set to a large enough number so that the residuals from the Dickey-Fuller regression are serially uncorrelated. Under the null hypothesis, $\alpha_1 = 0$ and the series is assumed to be nonstationary. This test was run with a constant and a trend, and table 1 reports the results of the Dickey-Fuller t -statistics for this general model.

From the results in table 1, the null hypothesis of nonstationarity could not be rejected, and therefore we conclude that the series are nonstationary, except for the Ontario commercial natural gas prices for the *deregulated prices era*, from December 1988 to December 1996. Furthermore, the first difference of each price series (Δp_t) was also tested for nonstationarity, and the null hypothesis could be rejected in each case. Therefore we concluded that the first differences of the tested price series are stationary, and as a result, the original price series contain a unit root.

In addition, the series for the Alberta border prices show a clear distinction between regulated and deregulated eras. In the former, the series exhibit a ladder shaped curve, which is a feature of regulated markets, where prices do not respond to market conditions and are less volatile. In contrast, after deregulation, the prices are driven by supply and demand with very little government intervention. The core market prices in Ontario exhibit a similar pattern, where

prior to deregulation the seasonal patterns were smaller in magnitude and more uniform, to the extent that the industrial market almost did not exhibit any significant seasonal patterns. After deregulation, however, these seasonal patterns are more visible, indicating a more price volatile market for natural gas.

One interesting point that was encountered in this research was that in the numerous papers that have dealt with this subject, there was no mention of the effects of seasonality on the results. In light of this, I decided to extend the analysis in order to investigate this possibility. In the attempt to remove the seasonal pattern in the core market prices, the X11 procedure³¹ in SAS was used. However it is important to note that the stationarity test results did not change with the seasonally adjusted data, and in all cases, except the Ontario commercial price series, the null hypothesis could not be rejected, indicating a nonstationary price series. The results of the seasonal adjustment exercise are plotted in figure 7. Therefore, since these results did not change the outcome of the analysis, it will be sufficient just to mention them in this section for the sake of completeness. In figure 7, the seasonally adjusted series trace the original series very well without the seasonal component, and for that reason, we conclude that the X11 procedure was successful in removing the seasonal component from the data.

³¹The X11 seasonal adjustment program in SAS is divided into 7 major parts. First it runs a diagnostic check on the data series, then performs preliminary estimates of irregular component weight, after that it estimates these components and estimates the seasonal, trend-cycle and irregular components. Finally, the program produces analytical tables and summary measures with charts.

	Test Statistic	Critical Value at 10%	Nonstationarity
Ontario Residential Jan 80 - Oct 87	-0.51318	-3.13	YES
Ontario Residential Dec 88 - Dec 96	-2.3637	-3.13	YES
Ontario Commercial Jan 80 - Oct 87	-1.3469	-3.13	YES
Ontario Commercial Dec 88 - Dec 96	-3.4852	-3.13	NO
Ontario Industrial Jan 80 - Oct 87	-1.0988	-3.13	YES
Ontario Industrial Dec 88 - Dec 96	-2.3090	-3.13	YES
Alberta Border Jan 80 - Oct 87	-1.4737	-3.13	YES
Alberta Border Dec 88 - Dec 96	-1.6263	-3.13	YES

Table 1 Results for Augmented Dickey-Fuller Tests

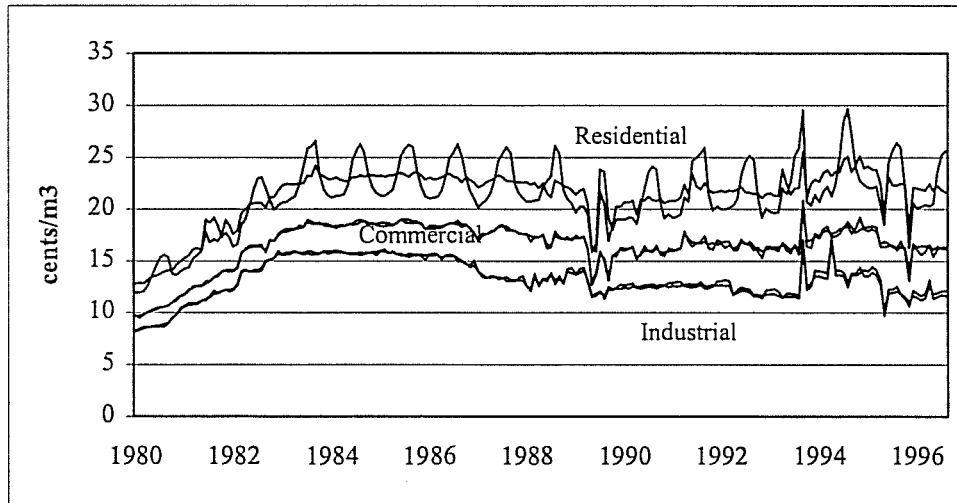


Figure 7 Original Series vs. Seasonally Adjusted Data

VI. EMPIRICAL ANALYSIS

In this chapter, the empirical analysis follows in the path of DeVany and Walls (1993) and King and Cuc (1996). The chapter tries to investigate two major issues. The first issue is in regards to the behavior of the natural gas price series in Ontario, on the one hand, and in Alberta on the other, during the *regulated prices era* and the *deregulated prices era*. The chapter tries to answer the question of whether or not deregulation and open access resulted in these two different markets coming together as a single national market for natural gas. The second major issue this chapter will investigate is the behavior of natural gas prices in the three segments of the Ontario downstream market: residential, commercial, and industrial. Again, the purpose of this analysis is to determine whether or not deregulation and open access had any effect on the Ontario consumer market segments in terms of price leadership.

After determining, in the preceding chapter, that each of the price series contains a unit root, and hence are nonstationary, except for the deregulated era in the Ontario commercial market, the next step was to test for cointegration using the Engle-Granger (1987) testing procedure. Granger (1981) introduced this remarkable link between nonstationarity and the concept of long-run equilibrium, which he called cointegration. In general, if two time series are $I(1)$ (integrated of order 1), then their linear combination is also $I(1)$. However, the error terms of this combination could be stationary, or $I(0)$, and in this case we can say that the two series are cointegrated. Therefore, if we find that prices from two markets are cointegrated, then this is an indication that geographical arbitrage working and that the two markets are reacting to the same fundamentals. The cointegration testing procedure involves two steps. First, a bivariate linear regression which represents the long-run equilibrium relationship between a pair of price series is estimated:

$$p_{j,t} = \alpha + \beta p_{i,t} + u_t$$

where $p_{j,t}$ is the first price series, $p_{i,t}$ is the second prices series, and μ_t is the residual term from the regression. The second step involves testing the calculated least square residuals (μ_s) of this regression for nonstationarity using a modified version of the Dickey-Fuller unit root test, with the following first-order autoregressive model (AR(1)):

$$\hat{\mu}_t = \rho \hat{\mu}_{t-1} + v_t$$

then we test the null hypothesis $H_0 : \rho = 1$, If $|\rho| < 1$ then \hat{u}_t is stationary; however, if $|\rho| = 1$ then the errors are nonstationary. Because each of the price series is not stationary, except for the deregulated Ontario commercial prices, we are able to run the cointegration test on these pairs, and under the null hypothesis, we would reject nonstationarity of the residuals.

As a result, the cointegration procedure in Shazam, which combines testing for stationarity of the prices series and then testing for stationarity of the residuals of a linear combination, was performed on the three market pairs; Alberta border-Ontario residential, Alberta border-Ontario commercial, and Alberta border-Ontario industrial, with each pair divided into regulated and deregulated eras. The purpose of this test is to determine whether or not there is evidence of a long-run relationship between each of the six nonstationary price-pairs. If such evidence exists, then we can draw conclusions about markets' cointegration. The results are displayed in table 2. The null hypothesis of non-cointegration could not be rejected for all 6 price pairs at the 10% significance level (or more accurately, the null hypothesis of a unit root, or non-stationarity, of the residuals of the linear combination could not be rejected), which suggests

that the series are not cointegrated. These results are not what were expected, and are evidence that city markets are generally not as well integrated into the pipeline network as are field markets.³² These results could be attributed to a number of factors, among them high transmission charges and residuals that do not reflect the true cost of gas in the core market of Ontario. Furthermore, the Ontario market receives its natural gas requirements mainly from Alberta through the TransCanada PipeLines system only, so in effect there is a shortage of alternative transmission lines.

	Test Statistic	Critical Value at 10%	Non-cointegration
Border - Residential Jan 80 - Sep 87	-1.3021	-3.50	YES
Border - Residential Dec 88 - Dec 96	-1.7678	-3.50	YES
Border - Commercial Jan 80 - Sep 87	-2.3601	-3.50	YES
Border - Commercial Dec 88 - Dec 96	-1.7073	-3.50	YES
Border - Industrial Jan 80 - Sep 87	-1.9259	-3.50	YES
Border - Industrial Dec 88 - Dec 96	-2.1542	-3.50	YES

Table 2 Cointegration Results across the Alberta Border and Ontario Market Segments (Augmented Dickey-Fuller test statistics)

Figure 8 compares Alberta border prices with each of the three Ontario consumer markets. The first thing to notice is that after the sharp decrease in the Alberta border prices in 1988, consumer prices in Ontario reacted only slightly to that decrease. This implies that the

³² Walls (1994) reaches a similar conclusion.

savings were not fully passed on to Ontario consumers, and that there was a compensation effect reflected in higher transmission, transaction, or residual costs. This conclusion comes from the basic idea that if the two markets became fully integrated into a national market, then the difference in the prices across the two regions will be the costs of transportation and transactions. Furthermore, if these transportation and transaction costs remained highly volatile, and the random variations in these costs increased instead of decreased then cointegration will not occur, and in fact the two markets could diverge further away from equilibrium. Figure 9 illustrates this idea using a plot of the price differentials between Alberta border prices and each of the three Ontario markets. Price differentials seem to have increased and become more volatile after deregulation, rather than the other way around.

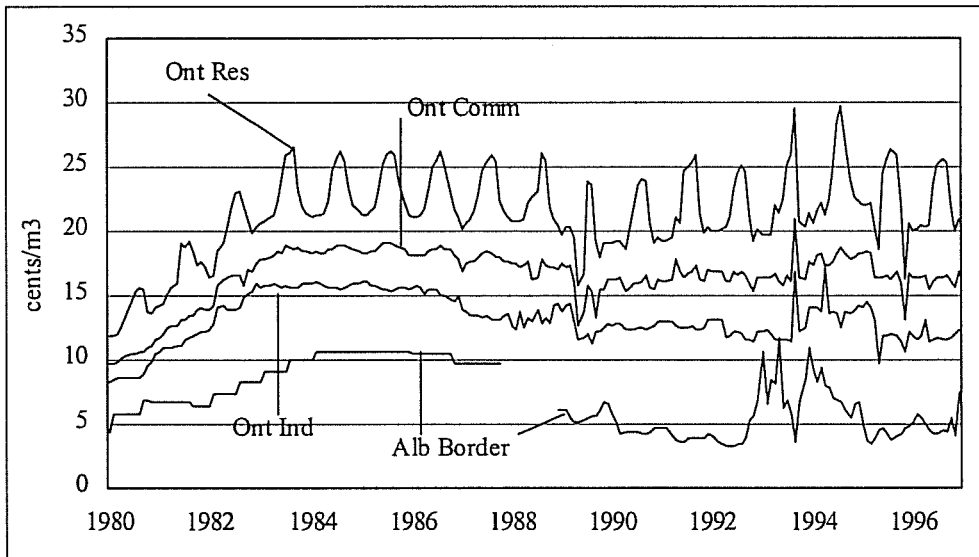


Figure 8 Ontario Gas Prices vs. Alberta Border Price

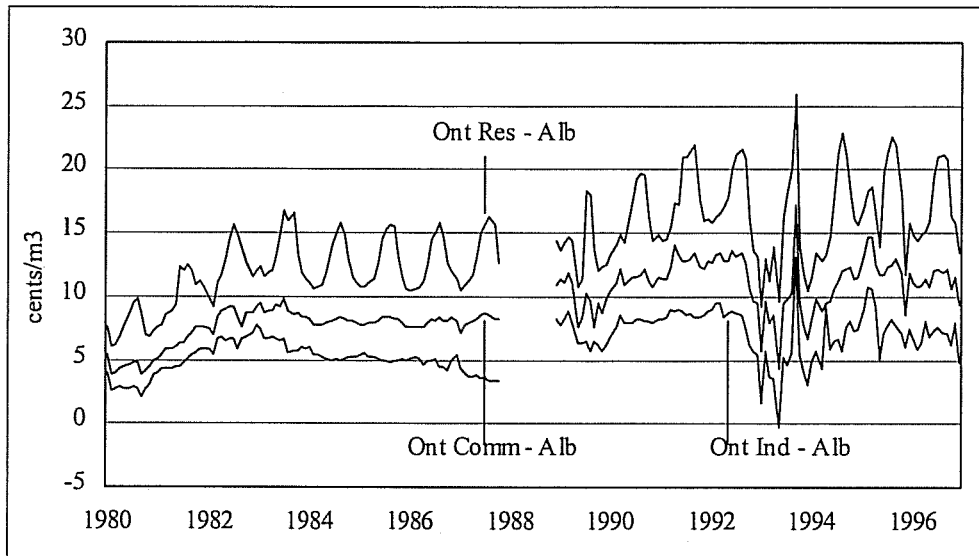


Figure 9 Price Differentials between Ontario Market Segments and Alberta

Another factor that could contribute to the non-integration of the two markets is what is referred to as 'geographical bias',³³ where the degree of price integration depends on the distance between the market pairs, and as the distance increases, the link between the two markets weakens.

In its Natural Gas Markets Assessment of 1995, the National Energy Board compared gas prices at Empress with those in other markets in Canada and the U.S., and concluded that the lack of available gas pipeline transportation from western producing basins to the larger consuming markets of the east has resulted in an over supply of gas in the western half of North America.³⁴ The NEB's conclusions are consistent with the results obtained in this paper, that these two markets are either driven by completely different fundamentals or the problem lies in the transportation sector of this industry.

³³King and Cuc (1996) discuss this concept.

³⁴The National Energy Board (1995, p. 20).

Next we turn our attention to the second major issue of this chapter, which is the behavior of natural gas prices in the three segments of the Ontario downstream market: residential, commercial, and industrial. Here, we try to determine whether or not deregulation and open access had any effect on the Ontario market segments in terms of price leadership. The idea here is to investigate whether or not the transformation of the structure of the market for natural gas in Canada had an effect on the price relationships among the three segments of the Ontario market.

In order to accomplish that, two tests were performed, a cointegration test and a Granger Causality test. The cointegration test was performed on the three market pairs, residential-commercial, residential-industrial, and commercial-industrial, using a similar procedure to the one discussed above. The results reported in table 3 indicate a very weak relationship between these markets. The hypothesis of non-cointegration could not be rejected in all but the residential-commercial pair. In other words, prices in the commercial and residential markets seem to be driven by similar fundamentals. However, the same could not be said about the residential-industrial, and the commercial-industrial price pairs, in both the regulated and deregulated eras. From these results one concludes that deregulation and open access did not have an impact on the Ontario consumer market, since the price relationship between residential and commercial segments existed before and after deregulation. Furthermore, the absence of a price relationship between residential-industrial, and commercial-industrial market pairs in the regulated era did not change after deregulation.

The other test that was performed, however, is more important in terms of determining the effects of deregulation and open access on the Ontario market segments. Using the concept of causality introduced by Granger (1969), we are able to determine, given two variables, whether one variable y_{1t} is Granger-caused by y_{2t} if current and past information on y_{2t} can help improve

the forecasts of y_{it} .³⁵ The test is performed using a Vector Autoregressive model (VAR), which produces a consistent estimate provided that the assumptions of non-seasonality and stationarity are satisfied. In other words, the time series need not have trends, seasonal patterns, or variances that change over time.

	Test Statistic	Critical Value at 10%	Non-Cointegration
Res. - Comm. Jan 80 - Oct 87	-3.8767	-3.50	NO
Res. - Comm. Dec 88 - Dec 96	-5.8327	-3.50	NO
Res. - Ind. Jan 80 - Oct 87	-2.3965	-3.50	YES
Res. - Ind. Dec 88 - Dec 96	-2.7512	-3.50	YES
Comm. - Ind. Jan 80 - Oct 87	-2.1017	-3.50	YES
Comm. - Ind. Dec 88 - Dec 96	-3.2502	-3.50	YES

Table 3 Cointegration Results across Ontario Market Segments
(Augmented Dickey-Fuller test statistics)

In order to satisfy these model assumptions, the previously seasonally-adjusted price series for the Ontario market segments were used in this test. In addition, the first difference was used in order to satisfy the stationarity assumption. After that the Granger procedure in Shazam was used to test for Granger Causality. The procedure performs two hypothesis test as follows:

Test 1 H0: Y2 does not Granger-cause Y1

Test 2 H0: Y1 does not Granger-cause Y2

³⁵ Griffiths, Hill, and Judge (1993, pp. 695-696).

Each of these two tests is performed using a VAR model with one lag and 4 lags, VAR(1) and VAR(4). The choice of the number of lags is arbitrary, and is used here to determine whether or not including more past information will significantly alter the results. For example the VAR(1) equation is:

$$\text{VAR}(1) : y_{t1} = b_{11} + b_{12}y_{t-1,1} + b_{13}y_{t-1,2} + u_{t1}$$

where y_2 does not Granger cause y_1 if and only if $a_{13} = 0$. For VAR(4) the equation is:

$$\begin{aligned} \text{VAR}(4) : y_{t1} = & a_{11} + a_{12}y_{t-1,1} + a_{13}y_{t-1,2} + a_{14}y_{t-2,1} + a_{15}y_{t-2,2} + a_{16}y_{t-3,1} + \\ & a_{17}y_{t-3,2} + a_{18}y_{t-4,1} + a_{19}y_{t-4,2} + v_{t1} \end{aligned}$$

where y_2 does not Granger cause y_1 if and only if $a_{13} = a_{15} = a_{17} = a_{19} = 0$.

The results of this test, as shown in table 4, indicate a different story than what was concluded using the cointegration tests. The null hypothesis that Y_2 does not cause Y_1 was rejected in all three price pairs for the regulated era at the one and five percent levels. In other words, it was found that commercial prices Granger-cause residential prices, industrial prices Granger-cause residential prices, and industrial prices Granger-cause commercial prices. The null hypothesis that Y_1 does not cause Y_2 could not be rejected at both the one and five percent levels. This result clearly indicates that in the regulated era there was a clear relationship among the Ontario market segments in terms of price leadership, with commercial prices leading residential prices, industrial prices leading commercial prices, and industrial prices leading residential prices. The results were the same using four lag periods.

On the other hand, these price relationships vanished after deregulation, with the null hypothesis not being rejected for both tests, using one and four lags, at the one and five percent

levels. In other words, after deregulation, prices in the three Ontario market segments became independent of each other, and prices in one market segment did not lead those of another.

It is important to mention, however, that a study by Toda and Phillips (1994) concluded that causality tests are valid only when there is sufficient cointegration with respect to the variables whose causal effects are being tested. However, there is no valid statistical basis in VAR's for determining whether the required sufficient condition applies or not. Furthermore, the VAR test suffers from size distortions in cases where tests are not valid asymptotically as chi-square criteria, and in general the test should not be used if the sample is smaller than 100 observations.

		NLAG = 1		NLAG = 4	
		Test 1	Test 2	Test 1	Test 2
	Y1 - Y2	F(1,88) = 6.85 at 1% = 3.92 at 5%		F(4,76) = 3.48 at 1% = 2.45 at 5%	
Regulated (Jan 80-Oct87)	Res. - Comm.	4.57	0.157	9.79	1.13
	Res. - Ind.	10.26	0.207	5.95	3.15
	Comm. - Ind.	10.5	0.750	4.42	1.17
Deregulated (Dec 88-Dec 95)	Res. - Comm.	0.780	0.720	0.490	0.470
	Res. - Ind.	0.727	0.227	0.259	0.522
	Comm. - Ind.	0.112	0.209	0.146	0.575

Table 4 Granger Causality Test Results across Ontario Market Segments

From the above analysis, we reach the following conclusions. With regards to the first issue under investigation, that is the effects of deregulation and open access on price linkages

between Alberta and Ontario, we found no significant differences in the price behaviour before and after deregulation came into effect. These results, which indicate a weak relationship between natural gas markets in Alberta and Ontario, lead to the conclusion that since deregulation, the two markets have not exhibited any clear linking mechanisms, and price cointegration has not occurred. Furthermore, these results can be attributed to a number of factors. Among them, we found an irregularity in the pricing mechanism of the natural gas delivered to Ontario. Residual costs, which include transportation and transaction costs, seem to have gone haywire after deregulation.

The second major issue that was investigated in this chapter was price linkages within the Ontario market segments for natural gas, before and after deregulation. Using the cointegration technique we concluded that deregulation and open access had no effect on the Ontario consumer markets. However, when we applied the more appropriate Granger causality test, we found that the price relationships that existed prior to deregulation seem to have disappeared after deregulation. Therefore we conclude that deregulation and open access have in fact caused a breakdown in the price relationships among the three Ontario market segments.

VII. CONCLUDING REMARKS

In this paper we have investigated the Canadian market for natural gas, and more specifically, the price linkages between the Alberta border prices for natural gas and the Ontario core market prices. We have also looked at the relationships between the prices in Ontario's market segments in terms of price linkages among the residential, commercial and industrial markets.

In 1985 a new era dawned on the Canadian markets for natural gas as a result of the advent of the *Western Accord* and the *Agreement on Natural Gas Markets and Prices*, which signaled the transformation of the market. This paper introduced the deregulation framework, and the key dates associated with the transformation of the market for natural gas from a heavily regulated industry into a more open environment where agents were allowed to conduct trades directly with each other. The unbundling of gas sales and services, and the emergence of spot markets and futures markets for natural gas, created a new business environment where end-users were given the opportunity to choose their suppliers and contract transportation services.

The paper also discussed the changes in Ontario's consumer market, with its three segments - residential, commercial, and industrial - and noticed a change in the demand structure for natural gas since 1995 between residential and industrial sectors. After a number of years of industrial natural gas consumption exceeding both commercial and residential consumption, there was a reversal of the relationship between the industrial and the residential sectors. After 1995 residential consumption of natural gas became larger than that of the industrial sector. This is evident in the sharp increase in residential consumption since the mid-1980s, while industrial consumption reached its peak by the late-1980s and has decreased since.

A number of papers have studied deregulation of the natural gas market. However, most have focused on the US side of the border which, to some extent, is very similar to the Canadian market. The crucial difference between the two markets, however, is that while most major US cities are served by at least two transmission pipelines, most major Canadian cities are limited to one. The limited number of studies on the Canadian market for natural gas, however, revealed some puzzling results, with some markets diverging instead of converging, and very weak linkages among consumer markets.

The methodology was based on the cointegration techniques described by Engle and Granger (1987), where they modeled the joint determination of two price sets through an error correction mechanism. The motivation behind this analysis was that after deregulation, economic forces would have prevented persistent deviations from the equilibrium condition, and would have allowed prices between two different market locations, or segments, to converge.

However, the results obtained in this study are somewhat puzzling. The introduction of open access and the deregulation of natural gas prices managed to change the structure of the market, and introduced new and innovative methods in gas trading. Furthermore, the Alberta border prices decreased dramatically as a result of deregulation. However, these price decreases were not passed on to the downstream market in the same magnitude. Instead, residual charges, which encompass transportation and transaction charges seem to have gone up and almost canceled out the decrease in the border prices. In addition, the volatility of these residual costs seems to have increased after deregulation, when it was supposed to decrease. Overall, the two markets seem to be evolving separately, and are being affected by different forces or key factors. Under these circumstances, a number of explanations could be offered in order to rationalize the behavior of these markets. First, there seems to be an effect exerted by an east/west split in the

natural gas market. This result was reached in another study discussed earlier in this paper, where prices and market linkages seem to be greater in the western half of North America, where most of the gas fields are located. In addition, pricing practices seem to be a major factor in these linkages as well, and preferential pricing practices in Alberta, which would have contributed to the weakening of market linkages.

In addition, due to the shortage of pipeline capacity, a number of pipeline expansion projects were initiated to solve this shortage problem. However, these expansions might have intensified the problem of weakening the linkages between the Ontario and the Alberta markets, even further. The reason is that costs of expanding the major link between the two provinces, the TransCanada Pipelines system, were passed on to consumers in terms of NEB approved toll increases. As a result, the decrease in the price for natural gas in Ontario after deregulation did not reflect the true decrease in Alberta border prices as a result of deregulation.

In Ontario, the three market segments do not seem to have clear linking mechanisms, except between the residential and the commercial markets. However, no clear relationship appears to exist between the commercial and the industrial markets or between the industrial and the commercial markets. In addition, the price-leadership relationships that existed prior to deregulation seem to have disappeared after deregulation. These results are not exactly what one might have expected to find after deregulation.

In conclusion, the law of one price does not seem to prevail in the Canadian natural gas market, at least not between Alberta and Ontario, and there is an increasing evidence of an east/west, upstream pricing/downstream pricing gap, that is creating price differentials between Alberta and Ontario. Furthermore, Ontario's market segments are also experiencing different

market forces that are controlling their pricing mechanisms, with no clear linkages among these market segments after deregulation.

Finally, it is possible that further deregulation is needed in Canada, especially at the provincial and pipelines levels. The problem seems to be more of a connectivity issue, related to pricing on the transmission network. Therefore further study is needed on this issue in order to determine the cause of these pricing disparities between Alberta and Ontario.

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APPENDIX

NATURAL GAS PRICES IN CENTS / M³ (CANADIAN)

Year / Month		Ontario Residential Prices	Ontario Commercial Prices	Ontario Industrial Prices	Alberta Border Prices
1980	JAN	11.94	9.66	8.26	4.3318563
	FEB	11.93	9.69	8.45	5.8406174
	MAR	12.1	9.81	8.61	5.8406174
	APR	12.66	10.08	8.66	5.8406174
	MAY	13.51	10.25	8.64	5.8406174
	JUN	14.48	10.46	8.64	5.8406174
	JUL	15.31	10.54	8.67	5.8406174
	AUG	15.62	10.56	8.63	5.8406174
	SEP	15.4	10.65	8.94	6.7993737
	OCT	13.81	10.99	9.47	6.7993737
	NOV	13.63	11.17	9.79	6.7297135
	DEC	14.02	11.6	10.48	6.7297135
1981	JAN	14.26	11.72	10.69	6.6942005
	FEB	14.39	12.1	10.94	6.6942005
	MAR	15.2	12.54	10.95	6.6942005
	APR	15.55	12.62	10.93	6.6942005
	MAY	15.98	12.66	11.17	6.6942005
	JUN	18.99	13.05	11.16	6.6942005
	JUL	18.68	13.08	11.49	6.6942005
	AUG	19.19	13.46	11.79	6.6942005
	SEP	18.47	13.48	11.83	6.4151074
	OCT	17.29	13.97	12.03	6.4151074
	NOV	17.73	14.04	12.23	6.4151074
	DEC	17.25	13.98	12.23	6.4151074

1982	JAN	16.38	13.98	12.33	6.4831722
	FEB	16.61	14.29	12.82	7.3709403
	MAR	18.48	15.82	14.05	7.3709403
	APR	19.03	16.18	14.21	7.3709403
	MAY	20.36	16.48	13.95	7.3709403
	JUN	21.95	16.49	13.96	7.3709403
	JUL	22.98	16.53	13.96	7.3709403
	AUG	23.11	16.6	14.06	8.2587084
	SEP	22.05	15.81	14.92	8.2587084
	OCT	20.93	17.05	15.09	8.2587084
	NOV	19.89	16.92	15.33	8.2587084
	DEC	20.36	17.44	15.96	8.2587084
1983	JAN	20.65	17.78	15.7	8.2413673
	FEB	20.71	17.8	15.85	9.1272713
	MAR	21.03	17.96	15.84	9.1272713
	APR	21.21	18.05	15.98	9.1272713
	MAY	22.28	18.42	15.78	9.1272713
	JUN	24.06	18.34	15.59	9.1272713
	JUL	25.9	18.96	15.79	9.1272713
	AUG	26.06	18.82	15.6	10.013175
	SEP	26.6	18.62	15.66	10.013175
	OCT	23.32	18.73	15.69	10.013175
	NOV	21.88	18.4	15.98	10.013175
	DEC	21.36	18.39	15.93	10.013175
1984	JAN	21.09	18.28	15.97	10.000007
	FEB	21.26	18.37	16.02	10.593668
	MAR	21.31	18.33	15.93	10.593668
	APR	21.44	18.35	15.82	10.593668
	MAY	22.42	18.55	15.68	10.593668
	JUN	24.72	18.64	15.6	10.593668

	JUL	25.66	18.91	15.64	10.593668
	AUG	26.3	18.97	15.54	10.557179
	SEP	25.49	18.85	15.65	10.557179
	OCT	23.38	18.7	15.78	10.557179
	NOV	22.1	18.59	15.88	10.557179
	DEC	21.57	18.48	15.86	10.557179
1985	JAN	21.31	18.34	16.02	10.548838
	FEB	21.26	18.31	16.13	10.548838
	MAR	21.59	18.45	15.75	10.548838
	APR	21.87	18.43	15.85	10.548838
	MAY	23.25	18.68	15.66	10.548838
	JUN	25.17	18.99	15.53	10.548838
	JUL	25.86	19	15.49	10.548838
	AUG	26.24	18.99	15.39	10.548838
	SEP	26.01	18.85	15.54	10.548838
	OCT	23.73	18.81	15.56	10.548838
	NOV	22.14	18.55	15.61	10.548838
	DEC	21.23	18.09	15.53	10.548838
1986	JAN	21.02	18.09	15.61	10.504351
	FEB	21.08	18.11	15.74	10.504351
	MAR	21.21	18.17	15.62	10.504351
	APR	21.72	18.16	15.17	10.504351
	MAY	23.06	18.45	15.5	10.504351
	JUN	24.99	18.67	15.44	10.504351
	JUL	25.45	18.65	15.52	10.504351
	AUG	26.28	18.91	14.93	10.504351
	SEP	25.14	18.53	14.93	10.504351
	OCT	23.12	18.53	14.7	10.504351
	NOV	21.79	18.11	14.58	9.70946

	DEC	21.04	17.76	15.07	9.70946
1987	JAN	20.14	16.92	13.97	9.71974
	FEB	20.6	17.43	13.72	9.71974
	MAR	20.9	17.6	13.42	9.71974
	APR	21.51	17.73	13.38	9.71974
	MAY	22.78	17.93	13.47	9.71974
	JUN	24.68	18.28	13.22	9.71974
	JUL	25.34	18.37	13.36	9.71974
	AUG	26.01	18.35	13.08	9.71974
	SEP	25.43	18.02	13.06	9.71974
	OCT	22.42	17.93	13.05	9.71974
	NOV	21.54	17.71	13.39	
	DEC	21.1	17.63	13.58	
1988	JAN	20.71	17.54	12.6	
	FEB	20.75	17.45	12.37	
	MAR	20.82	17.25	13.76	
	APR	20.9	17.29	12.55	
	MAY	22.11	17.59	13.23	
	JUN	22.71	16.2	13.04	
	JUL	23.2	16.35	13.83	
	AUG	26.13	17.85	12.77	
	SEP	25.44	17.38	13.34	
	OCT	21.83	17.13	12.79	
	NOV	20.98	17.12	14.22	
	DEC	20.54	17.1	14.34	6.09868
1989	JAN	19.65	17.5	13.76	6.0448
	FEB	20.25	17.19	14.25	6.0448
	MAR	20.26	17.35	14.37	5.4781
	APR	19.48	16.17	12.96	5.1003
	MAY	15.83	12.72	11.5	5.1003

	JUN	16.73	13.72	11.65	5.2892
	JUL	23.85	15.73	12.05	5.4781
	AUG	23.61	15.27	11.32	5.55366
	SEP	19.29	13.29	12.25	5.667
	OCT	18.01	15.52	12.17	6.0448
	NOV	19.01	15.45	12.45	6.68706
	DEC	19.04	16.29	12.74	6.49816
1990	JAN	19.01	16.23	12.66	5.7891599
	FEB	19.18	16.2	12.78	5.1049213
	MAR	19.18	16.4	12.87	4.2881339
	APR	18.58	15.29	12.41	4.4206827
	MAY	20.28	15.6	12.34	4.4063531
	JUN	21.88	16.01	12.41	4.4063531
	JUL	23.58	15.92	12.57	4.3311227
	AUG	24.12	16.04	12.47	4.2917163
	SEP	23.85	16.52	12.34	4.2917163
	OCT	20.65	15.63	12.51	4.4063531
	NOV	19.09	15.46	12.66	4.6714508
	DEC	19.53	16.24	12.91	4.6714508
1991	JAN	19.16	16.1	12.91	4.70011
	FEB	19.26	16.12	13.02	4.6607036
	MAR	19.49	16.32	13	4.0194538
	APR	21.15	17.87	12.61	3.7543562
	MAY	20.7	16.85	12.5	3.5286649
	JUN	24.64	16.39	12.45	3.6038953
	JUL	24.97	16.67	12.53	3.9083994
	AUG	25.39	16.93	12.71	3.9442234
	SEP	25.95	17.41	12.34	3.9836298
	OCT	21.46	16.25	12.36	3.9442234

	NOV	19.84	16.09	12.57	3.9442234
	DEC	20.29	17.01	13.06	4.1949915
1992	JAN	20	16.84	13.08	4.119761
	FEB	19.96	16.9	13.16	3.6647961
	MAR	20.13	16.91	13.09	3.5143353
	APR	20.37	16.03	11.71	3.288644
	MAY	21.04	16.1	11.95	3.2492376
	JUN	23.31	16.89	12.12	3.306556
	JUL	24.58	16.63	12.11	3.4391049
	AUG	25.18	16.91	11.97	3.4749289
	SEP	24.76	16.49	11.56	3.8904874
	OCT	21.2	15.92	11.55	5.2912061
	NOV	19.2	15.27	11.4	5.6673582
	DEC	20.08	16.4	12.22	6.8746273
1993	JAN	19.75	16.39	12.21	10.618236
	FEB	19.62	16.33	12.33	6.6131121
	MAR	19.73	16.34	12.06	8.4258069
	APR	22.01	16.65	11.57	8.0854789
	MAY	21.41	16.04	11.53	11.786099
	JUN	22.57	15.76	11.54	6.2333776
	JUL	25.17	16.59	11.53	6.8388033
	AUG	25.9	16.05	11.38	5.8178191
	SEP	29.57	20.86	16.81	3.6325545
	OCT	20.75	16.46	12.21	6.7635729
	NOV	20.35	16.24	12.56	8.4258069
	DEC	21.39	17.64	14.1	10.994388
1994	JAN	20.69	17.42	14.03	9.1750901
	FEB	21.64	18.09	13.99	8.2502702
	MAR	22.19	18.35	13.82	9.4455907
	APR	21.23	17.37	17.21	7.9432154

	MAY	22.5	17.4	13.6	7.7494785
	JUN	24.88	17.65	13.68	7.0951593
	JUL	28.42	18.25	13.53	6.9379765
	AUG	29.7	18.8	12.5	6.7186516
	SEP	27.24	18.31	13.69	6.0752987
	OCT	23.98	17.74	13.57	5.4684999
	NOV	22.73	18	13.86	6.5285701
	DEC	22.35	18.27	14.18	6.7186516
1995	JAN	22.06	18.29	14.01	4.9567419
	FEB	22.01	18.38	14.49	3.7248672
	MAR	22.24	18.27	14.13	3.5128532
	APR	20.37	16.4	13.18	3.9332259
	MAY	18.53	16.33	9.7	4.5619571
	JUN	24.47	16.46	11.86	4.7410724
	JUL	25.68	16.51	11.94	4.1854495
	AUG	26.4	16.28	12.05	3.7833539
	SEP	25.95	16.94	11.8	3.9990233
	OCT	22.18	16.01	11.36	4.1671724
	NOV	16.29	13.12	10.64	4.6350654
	DEC	20.61	16.69	12.19	4.7776266
1996	JAN	20.07	16.34	11.91	5.1943438
	FEB	20.23	16.47	11.64	5.7682439
	MAR	20.42	16.43	11.89	5.5306419
	APR	20.26	16.5	13.18	5.0298502
	MAY	20.51	15.42	11.36	4.5765788
	JUN	23.56	16.1	11.52	4.1488953
	JUL	25.2	16.34	11.73	4.1854495
	AUG	25.66	16.35	11.64	4.5034705
	SEP	25.24	16.52	11.53	4.4011189

	OCT	21.86	16.16	11.67	5.505054
	NOV	19.93	15.7	12.05	4.1233074
	DEC	21.01	16.93	12.42	7.577674