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Natural Gas Prices and Competition Among Natural Gas Pipelines

by

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ABSTRACT

This thesis examines the effects of competition in the North American interstate natural gas pipeline industry on the price of that commodity. Following the deregulation of the natural gas industry in the early 1990's, new pipelines were built to deliver natural gas to energy-hungry markets. This thesis uses standard empirical methods to demonstrate that the addition of competing pipeline firms delivering natural gas across state and provincial boundaries has led to a decrease in the price of natural gas in those markets affected. The reduction of market power prompted by the addition of new competitors and the consequent beneficial effect on the prices paid by consumers of natural gas proves that the once controversial deregulation of this industry should be considered a success.

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CHAPTER ONE: INTRODUCTION

The effectiveness of competition as a regulating force in industries typically considered as natural monopolies is an important area of study in industrial organization and regulatory economics. Sweeping changes in the regulatory arena took place with the realization of unsound monopoly assumptions and inefficient performance in vertically integrated industries characterized as natural monopolies such as the airlines, telecommunications, and various energy industries. Regulatory barriers and imperfect intervention from regulatory institutions were substantially reduced in favour of competitive forces in numerous segments of industries.

For instance, the electricity market does not need to consist only of a vertically integrated monopoly utility, which provides all the services associated with power. Instead, while the transmission aspect remains a regulated natural monopoly, competition can be introduced in the generation and distribution aspects of the industry to obviate the need for direct regulatory involvement since these are not characterized as natural monopoly.

This thesis explores the ability of competition to discipline prices in the natural gas transmission industry. The pipeline industry plays an important role because natural gas is predominantly transported by long-haul pipelines. While there is consensus that natural gas deregulation has improved the efficiency of the industry "with respect to the commodity natural gas itself which includes production and marketing, the impact on the efficiency of pipeline transportation is less clear".[1] In particular, "consumers have enjoyed competitive gas prices since 1986 that have been well below the level of regulated prices and it is only since 2000 that market prices for gas have exceeded the level of regulated prices."[2] Of interest also is the finding of Hariton and Milne (2000) that although deregulation led to the pipelines "changing the way they operate by opening up their systems to third parties on a non-discriminatory basis, it did not result in reduced tolls and costs."[3] Gorak and Ray (1995) claimed that the deregulation has not resulted in "net benefits to all segments of the market" and that the transformation was pursued "with no realistic idea of the efficiency or equity impacts on the very consumers it is duty-bound to protect – captive consumers of interstate pipelines."[4] Given this, the goal of this study is to determine whether or not policies which promote competition are successful at achieving its intended beneficial outcomes. The following section provides an overview of the deregulation process of the natural gas industry.

The natural gas industry, like other network industries such as the telecommunications and electricity industries, has witnessed a fundamental revision to its structure and market institution in the mid 1980s with its deregulation. Awareness of the substantial costs associated with price controls and contractual rigidities led to the introduction of policies that foster competition and efficiency.[5] It is believed that while competition may be imperfect, some advantages of and efficiency gains from competition would nonetheless benefit consumers. Although the gas commodity market itself was deregulated, market participants need to be able to access the pipelines on an equal and non-discriminatory basis so buyers and sellers could transact directly with each other.

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[1] Hariton, G. and Milne, P., *Open Access in Network Industries.* Canada Transportation Act Review, p.7.
[2] *Ibid.,* p.7.
[3] *Ibid.,* p.7.
[4] Gorak, T. and Ray, D. (1995). "Efficiency and Equity in the Transition to a New Natural Gas Market." *Land Economics* 71 (3):368

Hence, although regulatory actions have led to a profound change in the traditional role of gas pipelines, regulation is nonetheless necessary as the provision of gas transportation services entails significant economies of scale and characteristics of natural monopolies.

Prior to the deregulation of the natural gas industry, pipeline companies bundled both the sale and delivery of natural gas to the downstream market. Gas shortages in the 1970s and excess supply in the mid 1980s however, led to FERC directing that pipeline companies in the U.S. become contract carriers in 1985 under FERC Order 636. As contract carriers, pipelines are obligated to provide unbundled transmission services and access to their transmission facilities to all shippers on an equal and nondiscriminatory basis. This meant that economic players in the gas industry could now take advantage of the pipeline network interconnections across the U.S. and Canada as they could ship gas directly from supply to demand regions. Ultimately, this ability gave rise to the development of numerous natural gas spot markets where thousands of daily transactions between shippers, buyers, and brokers take place. It was seen that the competitive pressures introduced by FERC Order 636 "might reduce costs and increase price elasticities of demand", resulting in lower local utility rate levels.[6]

With open access, transmission capacity on pipeline systems is now contracted for by a larger number of shippers as opposed to a handful of pipeline companies. Jess (1996) states that open access forces local distribution companies to secure their own gas supplies and compete with each other as well as third-party gas merchants for ultimate

[5] See Lyon (1990) for more details on the natural gas industry prior to its deregulation.
[6] Hollas D. (1999). "Gas Utility Prices in a Restructured Industry." *Journal of Regulatory Economics* 16:170.

customers such as industrial users.[7] Further, open access allows holders of transportation capacity to trade their transmission rights among themselves or transfer them to brokers and third parties. It is widely expected that with a more competitive climate in the pipeline industry, increased efficiencies will occur and be reflected through incentives to reduce cost of service. Consequently, consumers should experience not only improved service but a reduction in prices as well. Since Order 636 is the ultimate conclusion of a series of FERC regulatory restructuring policies between the 1980s and 1990s, its impact on the industry is the main focus of this study.

This transmission network feature in the pipelines industry is crucial as it links spatially separate markets. For a given network, potential arbitrage ensures prices are held in check in two spatially separate markets. A persistent price differential between any two markets that is greater than its transportation cost implies that price signals are distorted, resulting in allocative inefficiency whereby resources are misallocated between the two separate markets. "An efficient allocation of resources can only be achieved if potential arbitrage can ensure that the Law of One Price holds between two geographically separate markets."[8] Hence, if this seemingly basic economic property is violated, the function of price as a signal in a particular market is distorted rendering an inefficient allocation of resources.

Natural gas, like any other commodity, is moved between supply basins and market points so long as the difference between these two prices is at least greater than the cost of transportation. The value of capacity on a pipeline is the difference in gas

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[7] Jess, M. (1996) *Consumer Prices Reflect Benefits of Restructuring* Natural Gas 1996:Issues and Trends (December):99-112. Energy Information Administration, Office of Oil and Gas,p.99.

prices at the delivery and receipt ends of the pipeline. It is the most that one would be willing to pay for the right to move gas from the receipt point to the delivery point.[9]

This thesis is divided into five chapters. The following chapter provides a brief review of literature written on the topic of competition in the natural gas industry. The third chapter is a discussion on whether competition has had any effect on natural gas prices at city gates by using data found on city gate monthly gas prices in both the U.S. and Canada. The fourth chapter examines the extent of the connection between various gas spot markets using daily gas spot prices from 1993 to 2001 obtained from *Gas Dailies*. The final chapter offers conclusion and further improvements from this study.

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[8] De Vany, A. and D. Walls (1996). "The Law of One Price in a Network: Arbitrage and Price Dynamics in Natural Gas City Gate Markets". *Journal of Regional Science*. (36) 4, p. 555.
[9] This is excluding variable charges that must be paid for every unit transported.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

There are several studies in the economic literature which quantify the extent of competition in the natural gas transmission pipelines industry following FERC's implementation of open access policy. These studies are categorized into two major groups. Since an extensive amount of research was carried out by Arthur De Vany and David Walls on the effect of the open access policy on the gas pipeline industry, these studies fall under the group referred in this chapter as *law of one price*. Their studies predominantly seek to ascertain whether or not the natural gas spot prices found in physically separate markets satisfy the concept of "law of one price". In general, their studies found that the law of one price holds with gas prices converging to yield a more competitive gas market as the pipeline network became connected. All other studies related to the natural gas pipeline industry fall under the second group referred as *other studies*. The following provides more details on the studies.

2.1 Law of One Price

The law of one price is typically applied in purchasing power parity studies. In this context, the usual definition of the law of one price involves a commodity arbitrage that ensures prices in two different markets expressed in common currency unit are equated.[10]

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[10] Ardeni, P. (1989). "Does the Law of One Price Really Hold for Commodity Prices?" *American Agricultural Economics Association* p.1

Cointegration tests are commonly used to investigate the applicability of the law of one price. For instance, a study by Ardeni (1989) used nonstationarity and cointegration tests for a group of commodities in four countries to empirically show that the law of one price does not hold in the long run. He found that while exchange rates and commodity prices are nonstationary, they are not cointegrated[11], demonstrating the failure of law of one price as a long-run relationship.

Specific to the gas pipeline industry, the relevance of the "law of one price" up to the transmission and transaction costs across the transmission network is examined by several studies. The law of one price requires fully exploited arbitrage opportunities whereby a trader transacting between two markets can make no profits. The marginal value of the good is equalized when prices are equalized up to the cost of transacting. Failure of the law of one price generally results in incorrect price signals and hence inefficient allocation between markets.

De Vany and Walls (1993) examined whether the law of one price holds in the gas pipeline network grid by empirically testing whether prices at geographically dispersed locations are cointegrated. The study used the Engle-Granger cointegration technique on twenty daily natural spot prices. Their results suggest that prices at different points in the network do lie within the bounds that competition implies.

It has also been argued that one of the market effects of the industry restructuring is that a network, which connects the individual pipelines, was put in place. Walls (1993) employed cointegration techniques on 20 price series from 1987 to 1991 to find out if the open access policy has led the spatially separate market to become integrated. Markets are said to be cointegrated if the first differences between the 190 market pairs that is generated is stationary. His regressions show that the number of market pairs that are cointegrated increased from 46% in 1987 to 66% in 1991.

Walls (1994) argued that since price series from spatially separate commodity markets may be nonstationary, cointegration tests are appropriate in testing for market linkages. In his paper, he utilized the cointegration method tests within a larger vector autoregressive model developed by Johansen (1988, 1991) to test for market integration in the gas spot markets. His study found that spot markets at geographically separate locations in the pipeline network are strongly connected and most pairs are perfectly integrated.

According to Walls (1995), when the law of one price holds "the correct price signal will propagate and allocative efficiency will be obtained". Since bivariate regression equations do not account for simultaneous interaction among the full set of price series, this study uses Johansen's method of cointegration to make an inference on the process through which prices are determined. Johansen's multivariate cointegration method, which is based on a general vector autoregressive (VAR) model allows one to make inference on the number of binding price inequalities and determine the degree of competition in the open access pipeline network.

In a network with N nodes each representing a distinct geographic market in a transmission network, there are $N-1$ significant price spreads and the number of binding price spreads could be estimated empirically. "Johansen has shown that the test for the number of cointegrating relationships between a set of variables can be expressed as a

[11] Time series, which are individually nonstationary, are cointegrated if a linear combination of two or more

test of reduced rank of a regression coefficient matrix. The regression coefficient matrix can be estimated consistently using linear regression techniques, and the rank of the coefficient matrix is the number of cointegrating relationships between the variables."[12] Kugler and Lenz (1993) also applied Johansen's multivariate cointegration to test for the long-run validity of PPP on monthly flexible exchange rate vis-à-vis 15 currencies.

Results from the study of Walls (1995) indicate that there is a high degree of competition within and between production markets and city-gate markets are likewise integrated well with nearby production fields but less so with more distant production areas. This study has portrayed that pipeline deregulation was successful in linking together numerous geographically dispersed spot markets.

De Vany and Walls (1996) highlights the importance of the connection structure of arbitrage paths between markets in determining arbitrage limits and price dynamics and convergence. This work differs from their previous work because the price behaviour at the production field and city gates is simultaneously considered and the model is able to examine how "local bypass" authorized by state public utility commissions at the city gate opens paths that link it to the national market. A path arbitrage model of the law of one price in a multi-market setting is developed with the model accounting for geographic and intertemporal arbitrage paths within the network. This model also simulated the dynamics of prices with exogenous shocks and identified individual arbitrage paths that cause equilibrium prices to be violated.

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series can be stationary.

[12] Walls, D. (1995). "Competition, Prices, and Efficiency in the Deregulated Gas Pipeline Network: A Multivariate Cointegration Analysis." *The Journal of Energy and Development* (19) 1, p.6.

Natural gas prices at both production areas and city gate markets are empirically tested using a multivariate time-series model.. His results show that interstate pipelines becoming contract carriers and the bypass of local gas distributors resulted in the prices upstream and the city gates to converge to one market.

The cointegration technique widely used in the studies mentioned above is also utilized in other areas of study and one is found in Slade (2001). She employed the statistical test on causality by Granger (1969) and Sims (1979) in order to delineate a geographic market. If the price determination in one region is found to be interdependent to the price determination in a different region and vice versa, then the two regions may actually belong to a common market and be linked to each other. A simple correlation coefficient between two time series is used to identify if petroleum product prices in different geographic regions are correlated and therefore belong to a common market. Since the correlation may be spurious, the influence of common causal factors is purged.[13] Results from her study found that petroleum product prices in the Southeastern part of the United States is a local geographic market loosely connected to the Northeastern seaboard and entirely separate from the West coast.

What follows is a description of the differences between the studies by De Vany and Walls and what is contained in this thesis. One of the major differences is the time frame of the data used; with this thesis using a more updated price series in its regressions. While the majority of the studies by De Vany and Walls use price series data ranging between 1987 and 1994, this study has price series data ranging between 1990 and 2001.

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[13] Slade, M.,(1986). "Exogeneity Tests of Market Boundaries Applied to Petroleum Products." *The Journal of Industrial Economics*. 34(3),p.3.

Having available a longer and more recent time frame on prices allows one to have more information and insight to the pipeline industry as a "bigger" picture can be captured.

Another major difference in this thesis is that the Dickey-Fuller nonstationary tests failed to reject the null hypothesis that the price series found in this study is nonstationary. Hence, unlike the price series found in the studies above which were found to be nonstationary, this thesis treats the series to be stationary. A time series is considered nonstationary if the mean and variance of its stochastic process are not constant over time and the value of covariance between two time periods depends only on the distance or lag between the two periods and not on the time the covariance is actually computed.[14] Since the price series in this study is found to be stationary, cointegration techniques such as those developed by Engle and Granger and which were widely used in Wall's studies were not needed for this research.

2.2 Other Studies

Hollas (1999) offers an empirical examination of the impact of procompetitive policies on the pipeline segment of the gas industry. He assessed the residential, commercial, and industrial natural gas prices from the years 1985 to 1994 by estimating an empirical pricing model of local gas distribution utilities' pricing structure. He argued on a theoretical basis that increased competition, which decreases the firm's share along with its rival's share of industry output, would increase the absolute price elasticities of the customers' demands. For instance, if the industrial group ends up with greater access to transportation relative to the commercial and residential groups, then the price elasticity of the industrial group will increase by more than the elasticity of the residential and commercial groups.

Results from this empirical study, which tests for the effect of FERC policy on each customer class' group rates, found that the restructuring resulted in the prices paid for by industrial users to be relatively lower than those paid for by residential and commercial users. This means that the residential and commercial end users did not benefit from the restructuring as much as industrial consumers. A possible reason for this may be "the concern that costs from restructuring policies may be shifting to residential customers as industrial loads diminish".[15] This may be attributed to the fact the industrial group has the most ability to switch between fuels and hence in a better situation than the residential users to take advantage of the benefits from increased competition.

A related study by Jess (1996) compares the difference in real gas prices paid for by the different classes of customer for the years 1990 - 1995. She found that the electrical utilities and industrial users benefit most from the restructuring in that they saw the most reduction in real prices between 1990 and 1995 while the residential and commercial rates saw the least reduction.

Gallick (1993) considers how potential entrants are expected to influence the profitability of collusion by existing pipelines in the U.S. and the viability of any cartel that include both current and potential suppliers in a deregulated market. The threat of potential entry determines to what extent existing firms will exercise market power by restricting output and raising prices. He considers both the size of the nearby supplier

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[14] Gujarati, D. (1995). *Basic Econometrics* (3rd Edition). McGraw-Hill.
[15] Hollas, D. (1999). "Gas Utility Prices in a Restructured Industry." *Journal of Regulatory Economics* 16, p.182.

and the distance to the market in his selection of potential entrants. If it can be shown that the number of potential entrants in the bidding market for pipeline transportation is considerable enough to provide a competitive restraint on existing suppliers, a collusion to raise price is not plausible and regulation is not justified. He concludes that although the possibility for current suppliers to collude is the greatest in the short run and nearby suppliers may have insufficient divertible gas to pose a threat to the cartel in the intermediate run, all nearby suppliers are potential entrants in the long run.

McAvoy (2000) found that over the 1989-1994 period, transport prices measured based on gas deliveries between fifteen city pairs were at levels below FERC firm tariff rates between hub centers and major points of delivery. He found that "consumers saved almost $200 million/year in gas transportation charges on deliveries to nine major city gates alone". The market price of transportation service was estimated by calculating the difference between the receipt and delivered price of gas spot price at a given city pair or market hub. This difference is then compared against the regulated tariff transport rate in order to identify whether a given pipeline setting a given transport price between a city pair has an impact on the spot gas price differential of that pair. Gas price differential between city pairs of the same distance will also not vary with the number of pipelines between this pair. Except for one pair, he found that average city pair differential were less than tariff rates betweeen January 1989 to April 1994.

Results from McAvoy's (2000) Box-Cox equation[16], showed significant elasticities with the lagged price differential, transport distance, and the tariff variables with elasticity at means 0.537, 0.171, and 0.171 respectively. The elasticity on the tariff variable at its mean 0.171 suggests that a 10% increase in the tariff rate increase actual transport prices by 1.71%".[17] His data also does not support the notion that any hypothetical pipeline market power determines transport prices and price leveraging in the peak heating season.

McAvoy (2000) also tried to find out whether discounting in transportation prices depends on specific pipeline location power by setting the discount to be equal to the tariff rate minus the city pair price differential. The hypothesis is that "if pipelines were able to set rates as the number of pipelines increases at some location then this discount would depend on its previous level and on the HHI relevant to that city pair (location)". [18] For this test, he found that the lagged dependent variable is positive and statistically significant although the HHI variable while positive is not significant. A test to find the influence of pipeline concentration on competition in transportation markets was also conducted. To compare the degree of competition in the transportation market before and after FERC 636, the price differential for natural gas at two hubs is a function of the marginal cost of transportation, elasticity of demand, pipeline concentration, and conjectural variation."[19] Conjectural variation is an oligopoly model that distinguishes the different hypotheses regarding firm behaviour, measuring the scale of competition in a market. A Cournot conjecture equal to 0 (-1) suggests that the equilibrium in the conjectural-variations model is the same as the Cournot (Bertrand) equilibrium.[20] When the conjecture is 1, the conjectural-variations equilibrium is the same as the collusive or

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[16] The purpose of Box-Cox is to find a suitable transformation of a given variable given some optimal value of the transformation parameter to improve its fit with another variable.
[17] McAvoy P.(2000), *the Natural Gas Market*. Yale University p. 84.
[18] *Ibid.*, p. 85.
[19] *Ibid.*, p. 87.

monopoly outcome. McAvoy employed data from 1990 – 1997 on node spot prices in 22 origin and 9 destination nodes. He found the coefficient on HHI to be 0.215. Based on the assumption that the elasticity of demand is –0.7, he found the conjectural variation to be –0.65 in 1990 and -0.89 during the 1994 – 1997 period, which "implies that the degree of competition is severe, even though each region has only 3 or 4 equal sized carriers".[21]

If trade across markets is costless and the product is homogeneous, arbitrage would imply that prices will equalize throughout the market. A price differential that is greater than the transaction costs between markets will persist only if arbitrage fails to materialize.

Aside from the stationary nature of data used in this thesis, this research is also distinct from the studies above in that varying measures of competition are incorporated in the models. This includes not only the pipeline capacity concentration statistics but information on the number of competitors as well.

[20] Church, J and R. Ware (2000). *Industrial Organization A Strategic Approach*. McGraw-Hill p.273.
[21] McAvoy P.(2000), *the Natural Gas Market* . Yale University p. 87.

CHAPTER THREE: CITY-GATE MONTHLY PRICE MODEL

3.0 Introduction

This chapter examines the relationship of natural gas prices between supply states/provinces and demand states/provinces in both the U.S. and Canada. There are two models estimated. The first model uses the net interstate movement to identify the state pairs, and will be referred to as the *Net Interstate* model. The second model uses pipeline flows to identify state pairs, and will in turn be referred to as the *Pipeline Flow* model. The following sections describe each model in more detail.

3.1 Net Interstate Movement

This model empirically tests for the relationship of city gate prices between state pairs. State pairs included in the dataset are based on the net flow of natural gas between two neighbouring states.

3.1.1 Data Description

To identify the net flow of natural gas between states and state pairs, the data called the *Interstate Movements and Movements Across U.S. Borders of Natural Gas* is used. The data is found in Energy Information Administration's (EIA) Natural Gas Annual publication from 1990-2000. This dataset specifies how much natural gas is received (delivered) by each state from (to) its neighbouring state.

The data used on the city gate price series is the monthly average city-gate price by state found in EIA's Form EIA-857, "Monthly Report of Natural Gas Purchases and Deliveries to Consumers." Neither Hawaii nor Alaska is included in the data. The Canadian data is found in Statistics Canada Cansim title: *Crude and LPG Prices, Retail Product Prices, and Taxes, Canadian and Foreign, Natural Gas and Electricity, Residential, Commercial, and Industrial Prices.*

The data does not indicate actual quantities delivered from a specific producing state to a specific consumption state. It is easily the case that a state does not consume all the gas it received from its neighbouring producer state but instead, delivers some or all on to another consuming state. Thus, the state pairs included in this model are restricted only to neighbouring states as opposed to a state pair that consists of a producing state and a consuming state. Consider the following simple example.

Arkansas, a net demander of gas, is north of Louisiana, a big producer of gas. Although the data shows that Arkansas is a net receiver of gas from Louisiana, the amount actually consumed by the state of Arkansas and the amount delivered on to either Missouri (north of Arkansas) or Mississippi (east of Arkansas) cannot be determined. See Figure 1 below.

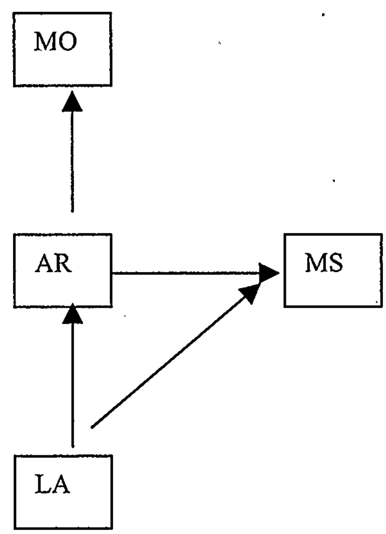

Figure 1: INTERSTATE NET GAS FLOW

The direction of the arrow shows the net flow of gas from one neighbouring state to another. A stylized map of the U.S. and Canada was developed (see Appendix A) much like Figure 1, which shows the net flow of gas between states and provinces. This map was used to identify the state pairs used in the model. From figure 1, since gas flows from Louisiana to Arkansas, one possible state pair would have the state of Louisiana classified as a supply state and the state of Arkansas as a demand state. Another possible state pair would have Arkansas as the supply state and Mississippi as the demand state. Since the price of gas in Arkansas, P_{AR}, is an opportunity cost of selling gas in Mississippi instead of Arkansas at P_{MS}, Arkansas is also included as a supply state

3.1.2 Model Discussion

Using the state pairs identified from the data, the following models are tested empirically to determine whether the price series between the state pairs are cointegrated. One hundred and five state pairs are generated in the estimation. These regressions essentially seek to determine whether price movements in one particular state have a bearing in another state and vice versa.

Model 1a $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 p_s D_R + \sum_{j=1} \delta_{i,j} D_{i,j}$$

$i\,j$ refers to a specific state pair where state i is a demand state and state j is a supply state

$p_{i,t}$ is the city-gate price of demand state, i , at time t

t is a time trend

D_R is a dummy variable for the regulation period

P_sD_R is the interaction variable between the price in the supply state and the regulation dummy.

$D_{i,j}$ is the dummy variable for each corresponding state pair

$i \neq j$ and $k = 1\ldots105$

Model 1b $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 p_s D_R + \phi_k D_R D_{i,j} + \sum_{j=1} \delta_{i,j} D_{i,j}$$

$D_RD_{i,j}$ is the interaction variable between the regulation era and the given state pair

Model 1c $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 num + \sum_{j=1} \delta_{i,j} D_{i,j}$$

dist is the distance between state i and j

num is the number of competitors in state j

To determine the effect of distance and the number of competitors on the price at the demand state, two more independent variables are added. The variables are: a) the distance between the two states considered and, b) the number of competitors between the two states. The price in the demand area is expected to increase with distance and decrease with the number of competitors.

The *dist* variable is calculated using a distance calculator found in the website called *indo.com*. In turn, this website service "uses data from the US Census and a supplementary list of cities around the world to find the latitude and longitude of two places, and then calculates the distance between them (as the crow flies)".[22] The biggest city of each province and state is used as the measuring point for each province/state. The *num* variable is the number of pipelines delivering gas to the demand state. The following provides an illustration. Suppose we want to quantify the effect of Louisiana gas prices and the number of competitors on gas prices in Arkansas. Suppose there are ten pipelines from Louisiana to Arkansas, five other pipelines from Texas to Arkansas, and another three from Okalahoma to Arkansas. The number of pipelines that would be included for this regression is eighteen as opposed to ten since competition from the other eight pipelines coming from Texas and Oklahoma serving Arkansas has to be captured as well.

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[22] http://www.indo.com/distance/ January 8, 2003

This information is from the "EIAGIS-NG Database" compiled by Jim Tobin of the Energy Information Administration's (EIA) Reserves and Natural Gas Division. This database includes the name(s) of the interstate pipelines serving each state for the years 1990 and 1994-2000. Since data is missing for the years 1991-1993, the average of the years 1990 and 1994 was calculated to fill in the missing years. Alaska and Hawaii were excluded in these analyses.

Model 1d

$$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 num + \beta_6 p_s D_R + \phi_k D_R D_{i,j} + \sum_{j=1} \delta_{i,j} D_{i,j}$$

TABLE 3.1 - DESCRIPTIONS OF VARIABLES USED IN THE ECONOMETRIC ANALYSES

Variable	Description
Price demand	City gate price in demand state ($U.S.dollars/m^{3})
Price supply	City gate price in supply state ($U.S.dollars/m^{3})
Time	Time trend
$D_{regulation}$	Dummy for regulation period; 0 for (1990-93) 1 for (1994-2000)
Distance	Distance between supply state and demand state
Number of competitors	Number of competitors in the demand state
Price supply * $D_{regulation}$	Interaction variable between the city gate price in the supply state and the dummy for regulation period
HHI	Herfindahl-Hirschmann Index between supply and demand states
Min	Minimum number of pipeline companies along the path of the supply and demand state
Max	Maximum number of pipeline companies along the path of the supply and demand state
Mean	Mean number of pipeline companies along the path of the supply and demand state

In Model 1a, the city-gate price in the demand state is regressed on the following variables: city-gate price in the supply state, a trend variable, a dummy variable for the regulation era, an interaction variable between the price in the supply state and the regulation era, and a dummy variable for each state pair. If price in the supply state is perfectly cointegrated with the price in the demand state, the coefficient β_1 is expected not to differ significantly from 1. The time variable, *t*, is included in order to capture the trend in prices. A dummy variable for the regulation era was included to capture the difference in the average price of natural gas before and after regulation. It takes on a value of 0 for the regulation era from 1990-1993 and a value of 1 for the post regulation era from 1994-2000. β_3 is expected to be negative because we expect prices to be lower with the deregulation in the industry. The $p_s r$ interaction variable denotes the difference in the relationship of gas prices between supply and demand state during and after the regulation era.

Models 1b-1d are variations of Model 1a. These are meant to determine how the coefficients, β's, change as more variables are added to the model. Model 1b includes one more interaction variable, $D_r D_{i,j}$, to Model 1a. This interaction variable interacts the regulation era with the dummy variable for each state pair and determines whether prices for any given state pair, $D_{i,j}$, have on average, gone up or down with deregulation. Model 1c incorporates both the distances between the supply and demand state, *dist*, and the number of competitors, *num*, in the demand state. Interaction variables were left out in this model and were included in Model 1d. The coefficient on the *num* variable should be negative because price is expected to be lower when there are more competitors.

TABLE 3.2 -VARIABLES USED IN INTERSTATE PIPELINE & PIPELINE MODELS - EXPECTED SIGNS AND DESCRIPTIVE STATISTICS

Theory	Variable	Expected Sign	Mean	Std. Dev.	Min	Max
Interstate Pipeline Model						
Dependent variable	Price demand		3.409	0.989	0.611	13.99
	Price supply	+	3.333	1.046	0.611	13.99
	Time	+	66.721	38.155	1	132
	$D_{regulation}$	-	0.638	0.480	0	1
	Distance	+	467.609	289.828	20	1404
	Number of competitors	-	6.112	3.734	1	23
	Price supply * $D_{regulation}$	+	2.119	1.831	0	13.990

3.1.3 Results

The results for the *Interstate Movements* models suggest that the city-gate prices between the neighbouring state pairs are not perfectly cointegrated. The coefficient that specifies the extent of cointegration between state pairs, calculated by summing the coefficients on the *price supply* and the interaction (*price supply* * $D_{regulation}$) variables ranges from 0.369 to 0.461 across the four models. The interaction variable is positive in the three models that it was included. This indicates that the price between the supply and demand state/province became more cointegrated, albeit not perfectly, with the deregulation of the industry.

The coefficient on the regulation dummy is negative on all four models. This implies that prices paid for by gas consumers have gone down following the deregulation in 1994. This provides a crucial demonstration of one of the most important benefits brought about by the deregulation, which are lower prices. The price decrease resulting from the deregulation varies in each model from 0.423 to 1.025.

In the two models where the *distance* and *number of competitors* variables were included, the coefficient on distance is positive. The coefficient on the *number of competitors* variable however, is also positive, indicating that as the number of competitors in the demand state/province increases, price rises as well.

The time trend variable is positive and ranges from 0.005 to 0.007. This suggests that over the time period 1990 and 2000, prices have been rising. For model 1b, a partial F test on the coefficients of the interaction variables $D_R D_{i,j}$ shows that these variables are jointly significant.

The results generated in this model offer another perspective on the extent of how prices across states and provinces are linked together. The results from the empirical data used in this model indicate that while prices between states are provinces are connected to some degree, from 0.369 to 0.401. This is unlike the results found in De Vany and Walls (1996), which found that the cointegrating parameter to be very close to one.

Unique to this model is the number of competitors being included as an independent variable in the regression. The results in this particular model however, failed to support the hypothesis that more competitors serving a demand state leads to lower prices.

TABLE 3.3 - RESULTS FROM NET INTERSTATE MOVEMENT MODEL

Price demand	Run 1	Run 2	Run 3	Run 4
Price supply	0.235 *** (16.342)	0.369 *** (44.942)	0.237 *** (13.428)	0.240 *** (13.585)
Time	0.007 *** (20.194)	0.007 *** (19.490)	0.006 *** (19.496)	0.005 *** (15.346)
$D_{regulation}$	-0.988 *** (-17.626)	-0.423 *** (-16.297)	-1.025 *** (-7.486)	-0.968 *** (-7.048)
Distance		0.001 *** (9.157)		0.002 *** (9.186)
Number of competitors		0.038 ** (2.245)		0.115 *** (4.966)
Price supply * $D_{Regulation}$	0.176 *** (11.375)		0.224 *** (11.276)	0.221 *** (11.135)
Observations	12612	12612	12612	12612
Adjusted R^2	0.9556	0.9551	0.9605	0.9606

t-stats in parenthesis
*significant at 10%, **significant at 5%, ***significant at 1%

Although the model did not produce the expected effects of increasing the number of competitors in a demand state/province, the model contained other essential features which deregulation has brought about to the natural gas transportation industry. More specifically, the results from the regressions demonstrate that prices did fall after the regulation era. Also, while the regression results does not support price cointegration between the supply and demand states/provinces, the results do indicate that prices were more integrated during the deregulation compared to the regulation period. Thus, the deregulation of the industry did bring about lower prices and increased price integration between supply and demand states/provinces. Another model referred to as the *Pipeline Flow* model below is created in this chapter.

Further improvements to the model should incorporate the bi-directional flows in some of the state pairs. In this model, only the net flow direction of gas was taken into account. For example, suppose Texas delivers 50 bcf of gas to Louisiana and Louisiana delivers 100 bcf of gas to Texas, the *Interstate Movement* model in this case, assumes that Louisiana is the supply state and Texas is the demand state. The model does not take into account the fact that Texas also delivers some gas to Louisiana.

3.2 Pipeline Flow Model

The *Interstate Movements* model is limited in that it identifies state pairs based on the import and export of natural gas from its neighbouring states only. More specifically, although the state of Texas ships natural gas to states other than its neighbouring states (New Mexico, Oklahoma, Arkansas, and Louisiana), this is not captured in the model due to data limitations. Consequently, another set of data is used to identify state pairs and is referred to as the *Pipeline Flow* model.

3.2.1 Data Description

Excepting for how state pairs are identified and the corresponding prices, distance, etc. of each pair, the *Pipeline Flow* model is largely similar to the *Interstate Movements* model. The *Pipeline Flow* model uses data from "EIAGIS-NG Database" compiled by Jim Tobin of the Energy Information Administration's (EIA) Reserves and Natural Gas Division. The database specifies the origin and destination state of each interstate pipeline companies along with the capacity of the pipeline for the years 1990 and 1994-2000.

Since data on inter-pipeline companies for the years 1991-1993 is not available, the average of the years 1990 and 1994 was calculated and allocated to the missing years. As in the previous model, Alaska and Hawaii along with the nine smallest consuming states were not included in this model because these states exhibits different demand patterns than those of the larger states. The variables in the model have the same interpretation as the first model and any new variables introduced will be discussed in the following sections.

3.2.2 Model Description

Model 5 $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 hhi + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Model 6 $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 hhi + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Model 7

$$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 \min + \beta_7 \max + \beta_8 mean + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Model 8

$$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 \min + \beta_7 \max + \beta_8 mean + \beta_9 hhi + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Model 9 $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 \min + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Model 10 $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 mean + \sum_{j=1} \delta_{i,j} D_{i,j}$$

To measure the effects of competition, four different variables were generated and included in the *Pipeline Flow* model. The variables are: a) the Herfindahl-Hirschmann Index (*HHI*) for each state pair, b) the minimum number of competitors along the path of the state pair (*min*), c) the maximum number of competitors along the path of the state pair (*max*), and d) the mean number of competitors along the path of the state pair (*mean*).

The *hhi* variable is the Herfindahl-Hirschmann Index between states *i* and *j*. It is calculated as "the sum of the squares of market shares and it is a common measure of market concentration".[23] In this model, the coefficient on the HHI is expected to have a positive sign, which implies that the more concentrated the market, the higher is the price.

The *min* variable is identified as the minimum number of pipelines along the path of states *i* and *j* . This is an important variable as it identifies potential bottlenecks in getting gas from the supply state to the demand state. The *max* (*mean)* variable is identified as the maximum (*mean*) number of pipelines along the path of states *i* and *j*. The coefficients on the *min*, *max*, and *mean* variables are expected to have a negative sign. This is because price decreases when there are more pipelines/competitors connected to a particular demand area.

To illustrate the usefulness of these variables, suppose we want to measure the price differential between Louisiana and Iowa. Suppose also that there are five pipelines between Louisiana and Arkansas but only one of those five pipelines delivers between Arkansas and Missouri and there are two pipelines between Missouri and Iowa. The *min* variable would capture the potential bottleneck between Louisiana and Missouri, which may occur for gas delivery between Arkansas and Missouri, as there is actually only one pipeline that can deliver gas. The *max* variable then is five, which is the maximum number of pipelines along the Louisiana and Iowa path and occurs between Louisiana and Arkansas.

Since most changes with respect to the degree of pipeline competition occurred in the Northeast and Midwest areas of the U.S., a set of regression was ran using data that includes only the Northeast and Midwest states and these are shown in models 11-16 below.

3.3 Midwest and Northeast markets only

Model 11 $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 hhi + \sum_{j=1}^{80} \delta_{i,j} D_{i,j}$$

Model 12 $$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 hhi + \sum_{j=1}^{80} \delta_{i,j} D_{i,j}$$

Model 13

$$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 \min + \beta_7 \max + \beta_8 mean + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Model 14

$$p_{i,t} = \beta_1 p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 \min + \beta_7 \max + \beta_8 mean + \beta_9 hhi + \sum_{j=1}^{80} \delta_{i,j} D_{i,j}$$

[23] Church and Ware (2001). *Industrial Organization: A Strategic Approach*. McGraw Hill: p.239.

Model 15 $$p_{i,t} = \sum_{k=1}^{80} \beta_k p_{j,t} + \beta_2 D_R + \beta_3 dist + \beta_4 hhi + \sum_{j=1}^{80} \delta_{i,j} D_{i,j}$$

Model 16 $$p_{i,t} = \sum_{k=1}^{80} \beta_k p_{j,t} + \beta_2 t + \beta_3 D_R + \beta_4 dist + \beta_5 p_s D_R + \beta_6 hhi + \sum_{j=1} \delta_{i,j} D_{i,j}$$

Models 11 – 14 proposes that the correlation coefficient among the eighty state pairs generated from the Northeast and Midwest regions is the same in that the extent of the price linkage from one state pair is the same as the next state pair. To assess whether or not this is so, regressions were ran to allow the correlation coefficients among the state pairs to differ from each other. This is captured in Models 15 – 16; whereby the interaction of a state pair dummy variable with the supply state price, $p_{j,t}D_{i,j}$, is introduced. While the differential intercept coefficient, $\delta_{i,j}$ indicates by how much the intercept differs from one state pair to another, the coefficient $\beta_{i,j}$, is the differential slope coefficient, which allows us to differentiate between the correlation coefficient among the state pairs.

TABLE 3.4 - VARIABLES IN THE INTERSTATE & PIPELINE FLOW MODELS - EXPECTED SIGNS & DESCRIPTIVE STATISTICS

Theory	Variable	Expected Sign	Mean	Std. Dev.	Min	Max
Pipeline Flow Model						
Large Demand States						
Dependent Variable	Price demand		3.472	0.996	0.793	13.988
	Price supply	+	2.873	0.968	0.611	10.192
	Time	+	66.496	38.122	1	132
	Dregulation	-	0.636	0.481	0	1
	Distance	+	1366.252	685.819	189	3366.000
	Number of competitors	-	6.080	2.960	1	13
	Price supply * Dregulation	+	1.784	1.543	0	1
	HHI	+	0.322	0.200	0.087	1.000
	Min	-	2.623	1.790	0	10
	Max	-	4.068	2.563	0	10
	Mean	-	3.347	1.993	0	10
Northeast & Midwest States						
Dependent Variable	Price demand		3.630	1.029	1.463	13.988
	Price supply	+	2.759	0.965	0.819	9.648
	Time	+	66.498	38.113	1	132
	Dregulation	-	0.636	0.481	0	1
	Distance	+	1585.434	703.153	346	3366
	Number of competitors	-	6.623	2.876	2	13
	Price supply * Dregulation	+	1.738	1.521	0	1
	HHI	+	0.250	0.133	0	0.698
	Min	-	2.880	1.687	0	7
	Max	-	4.490	2.295	0	8
	Mean	-	3.672	1.837	0	7

3.3.1 Results

The results from the *Pipeline Flow* model do not support perfect cointegration between the state pairs identified. The coefficient on the cointegration variable ranges between 0.384 and 0.528 in models 5–10 (see Table 2) and .526 – 0.545 in models 11 – 13 (see Table 3). In the model that allows the correlation coefficient to vary from one state pair to another, the correlation coefficient on the base pair, which are Louisiana and Illinois in this model is 0.89 and significant. Based on the regression in Model 15, the number of state pairs out of the 79 pairs which has a statistically significant differential slope coefficient at the 5% significance level is approximately 65%. This implies that approximately 52 out of the 79 state pairs have a different correlation coefficient than the base pair, Louisiana and Illinois. Based on this regression, the data fails to support the hypothesis that prices between state pairs are highly linked with each other.

For both Models 15 and 16, a partial F-test on the differential slope coefficients rejects the hypothesis that the coefficients are jointly zero. This implies that the degree of correlation among the various 80 state pairs included is not equal to each other. A partial F-test on the differential intercept coefficients rejects the hypothesis that these coefficients are jointly zero. Also, an F-test on both differential slope and intercept coefficient also rejects that hypothesis that these coefficients are jointly zero. This means that not only is the extent of price correlation dissimilar among state pairs but the intercept terms as well.

The time trend variable is positive and significant, between 0.007 and 0.01, suggesting that prices have been trending up over time. The coefficient on the regulation dummy is negative on all the models estimated except in the model where the correlation coefficient is designed to vary among the different state pairs, Model 15. This indicates that prices have gone down during the deregulation (1994-2000) era relative to the regulation era (1990-1993). The price decrease resulting from the deregulation ranges between 0.436 and $1.427. The interaction variable, which interacts the price in the supply state/province and the regulation period, is positive in the models where it was included and ranged between 0.197 and 0.374. This denotes that although prices are not perfectly cointegrated between supply and demand states/provinces, prices became more cointegrated when the industry was deregulated. The distance variables are all positive, which means that the greater the distance is between the demand and supply state/province, the higher is the price in the demand state/province.

The *HHI* coefficients are positive and significant in the regressions where only the Northeast and Midwest demand states are included. This suggests that for a given supply and demand pair, the price in the demand state/province increases with market concentration. The *HHI* coefficients range between 2.785 and 3.668. However, while the *HHI* coefficients are positive in regressions 6 – 11, they are not significant. In Model 15, while the *HHI* coefficient is significant, it is negative and hence, exhibits the wrong sign.

The coefficients on the *min*, *max*, and *mean* variables are non-conclusive as results are largely mixed and non-significant. The coefficients of the *min* variable in runs 7 – 9 are not significant and neither are the coefficients in runs 13 – 14. Although the coefficients on the *max* variable in runs 7 and 8 are significant at the 10% level, they are positive. Further, in the models which includes only the Northeast and Midwest, the coefficients of the *max* variable is not significant in runs 14 and 15 and the results are mixed. The *mean* coefficients in runs 7 and 8 are negative and significant only at around the 20% level and the coefficient in run 10 is positive but not significant. The *mean* coefficients in runs 13 and 14 are mixed and not significant.

A partial F-test on the differential intercept coefficients for Models 11-14 rejects the null hypothesis that these coefficients are jointly zero. This implies that the intercept (or constant) term varies from state pair to state pair.

TABLE 3.5 - RESULTS FROM PIPELINE FLOW MODEL

Price demand	Run 5		Run 6		Run 7		Run 8		Run 9		Run 10	
Price supply	0.384	***	0.154	***	0.154	***	0.153	***	0.154	***	0.153	***
	(47.655)		(14.134)		(14.028)		(14.014)		(14.136)		(14.021)	
Time	0.01	***	0.009	***	0.008	***	0.008	***	0.008	***	0.008	***
	(34.435)		(30.060)		(30.033)		(29.454)		(30.224)		(29.955)	
$D_{regulation}$	-0.436	***	-1.423	***	-1.426	***	-1.427	***	-1.422	***	-1.424	***
	(-19.777)		(-36.648)		(-36.693)		(-36.684)		(-36.613)		(-36.642)	
Distance	0.007	***	0.0009	***	0.0007	***	0.0009	***	0.0007	***	0.0007	***
	(33.208)		(41.644)		(33.806)		(34.811)		(33.964)		(33.629)	
Price supply $*D_{regulation}$			0.3715	***	0.374	***	0.374	***	0.371	***	0.372	***
			(30.513)		(30.538)		(30.539)		(30.410)		(30.447)	
hhi	0.032		0.115				0.099					
	(0.152)		(0.564)				(0.475)					
Min					0.017		0.018		-0.12			
					(0.149)		(0.163)		(-0.480)			
Max					0.232	*	0.231	*				
					(1.952)		(1.946)					
Mean					-0.252		-0.25				0.019	
					(-1.111)		(-1.104)				(0.740)	
Observations	17540		17540		17540		17540		17540		17540	
Adjusted R^2	0.957		0.9592		0.9592		0.9592		0.9592		0.9592	
t-stats in parenthesis												
*significant at 10%, **significant at 5%, ***significant at 1%												

TABLE 3.6 - RESULTS FROM NORTHEAST AND MIDWEST PIPELINE FLOW MODEL

Price demand	Run 11	Run 12	Run 13	Run 14	Run 15	Run 16
Price supply	0.44 *** (39.405)	0.297 *** (19.547)	0.348 *** (23.365)	0.255 *** (16.146)	0.8916 *** (9.423)	0.5605 *** (6.014)
Time	0.01 *** (25.717)	0.01 *** (24.164)	0.007 *** (18.089)	0.009 *** (20.864)		0.007 *** (18.616)
$D_{regulation}$	-0.453 *** (-14.589)	-1.048 *** (13.741)	-0.885 *** (-16.995)	-1.117 *** (-20.884)	0.0617 *** (3.433)	-1.261 *** (-20.831)
Distance	0.001 *** (15.759)	0.001 *** (16.848)	0.001 *** (13.479)	0.0006 *** (5.877)	0.002248 *** (7.587)	0.00094 *** (3.203)
Price supply * $D_{regulation}$		0.237 *** (13.741)	0.197 *** (11.478)	0.271 *** (15.408)		0.3154 *** (15.359)
hhi	2.785 *** (13.189)	3.668 *** (16.754)		3.498 *** (15.908)	-4.868 *** (-14.472)	-2.519 *** (-7.416)
Min			-0.021 (-0.084)	0.312 (1.269)		
Max			-0.123 (-0.473)	0.24 (0.934)		
Mean			0.493 (0.980)	-0.253 (-0.507)		
Joint F on State Pair Dummy Variables	F(78,10473) = 71.82 ***	F(78,10473) = 72.45 ***			F(78,10394) = 14.53 ***	
Joint F on Differential Slope Coeficient	F(78,10473) = 71.82 ***	F(78,10473) = 72.45 ***			F(79,10394) = 11.01 ***	
Observations	10556	10556	10556	10556	10556	10556
Adjusted R^2	0.953	0.9539	0.9531	0.9542	0.4124	0.4497

t-stats in parenthesis
*significant at 10%, **significant at 5%, ***significant at 1%

The Pipeline Flow model on the whole, is successful in capturing the effects of deregulation in the industry. In particular, the regression results illustrate that prices fell during the deregulation period and while the regression results does not support perfect price cointegration between the supply and demand states/provinces, the results indicate that prices became more integrated after the deregulation. Furthermore, the *hhi* variable invariably supports the theory that higher market concentration results in higher prices in the Northeast and Midwest regressions.

The results from the *min*, *max*, and *mean* variables are mixed and not significant. This could be due to how these variables were generated. Consider the following simplified example (Figure 2):

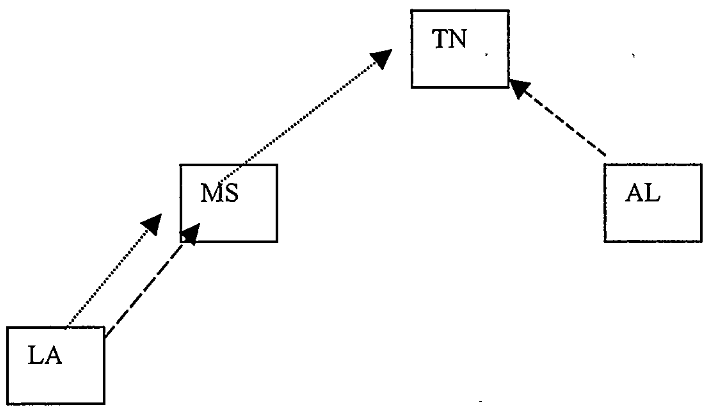

Figure 2: Pipepline flow model

In Figure 2, Louisiana (LA) supplies gas to Mississippi (MS) and Tennessee (TN)and Alabama (AL) supplies to Tennessee as well. From Figure 2, one state pair is LA – TN since there is a pipeline that takes gas from Louisiana to Tennessee. For that state pair, the *min* variable is 1, because along the path from LA – TN, the minimum number of pipeline companies that serve LA – TN is a segment from MS – TN where there is only one pipeline company. The *max* variable is 2, because along the path of LA – TN, the most number of pipeline companies is 2, which is the LA – MS segment. The *Pipeline Flow* model however, does not incorporate pipeline companies such as the one from LA – TN which serve Tennessee so although the *min* variable between LA – TN shows only one company, that one company actually faces competition from the pipeline company that serves AL – TN.

To further improve the model, a *competition* variable should be generated that is able to take into account competition from other state pairs as well. Also, daily spot prices, instead of monthly city-gate prices, would further improve the model. This is because dailies prices better reflect the value of gas at the margin. The problems associated with averaging and seen in monthly data, which averages prices, is also avoided when data on dailies is instead used.

3.4 Conclusion

Although each model has its own weaknesses, the models were successful at capturing the essential features which deregulation has brought to the natural gas pipeline industry. The regressions from the models demonstrated that the deregulation of the industry did bring about lower city-gate prices and increased price integration between supply and demand states/provinces. Pipeline market power has been greatly reduced as pipeline companies move from merchant to contract carriers.

A possible reason as to why the transportation sector is not as competitive as originally intended is that capacity allocation system is not as flexible and efficient. For example, pipeline transportation capacity is allocated based on a first-come first-served basis rather than the shipper's willingness to pay for the transportation capacity. Shippers are able to sell their extra long-term firm capacity to others at market prices on the secondary market.

Standard pricing structure has largely been based on the traditional cost-of-service regulation. Currently, shippers engage themselves in long-term firm transportation service, a contract entitling shippers to reserve a given amount of capacity on the pipeline. A shipper with reserved capacity on a pipeline may choose to release its capacity in the secondary market, also known as "capacity release". The pipeline may also market any unused capacity as "interruptible service". The pipeline tariff structure has two components; the long-term firm transportation tariff, intended to cover the fixed costs of the pipeline and the variable tariff to cover the variable cost of transportation.

CHAPTER FOUR: GAS DAILIES SPOT PRICES MODEL

4.0 Introduction

A regulatory regime that primarily depends on the marketplace was established in the natural gas industry with the intent that this would provide mechanism to allocate gas at the most efficient pricing. The development of natural gas spot markets stemmed from the gas pipeline deregulation in 1985. Prior to deregulation, gas pipelines acted as merchant carriers and they offered only bundled gas. That is, the integrated pipeline companies bought natural gas upstream, delivered it, and sold the gas downstream through long-term contracts. Further, as merchant carriers, they are not obligated to transport gas for others. This meant that customers could only buy gas from pipelines with which they are connected.

Following deregulation, gas pipelines became contract carriers and shippers can purchase transportation services only while making their own arrangements directly with the producers. As contract carriers, pipelines are legally obligated to ship the commodity without discrimination where tolls are regulated and based on cost to be just and reasonable. With pipelines companies as contract carriers, spot markets began to flourish since the sellers and buyers are now able to get their gas at the consumption point.

Spot markets require that market participants who buy and sell gas have access to the gas distribution system so they can deliver the product to where demand is. With deregulation, pipeline customers and gas brokers can exchange and combine transportation rights on several connecting pipelines. This allowed these buyers and sellers to contract capacity on pipeline systems. The spot market has become a reliable index of the underlying value of natural gas as the spot market has become established as the standardized place from which buyers and sellers make up for their supply and demand imbalances.

The Law of One Price in a spatial market requires that in the long run, the price in the first market should differ from the price in the second market by the transportation cost. This requires that economic agents cannot consistently profit by buying the commodity at one market by selling it in the other market.

This chapter is structured as follows. The following section explains the foundation which the empirical test is based upon. The third section describes the data and the regressions ran. The fourth section offers the results from the regression and the last section offers conclusions.

4.1 Theory

Related to these models is a study by Walls (1994), which looks at the nature of prices in the natural gas industry. Using natural gas spot price series from 1989-1990 at twenty nodes throughout the U.S. pipeline network, which was found to be nonstationary, Walls applied cointegration techniques to measure market linkages between market pairs when the data are nonstationary. His test was based on the estimable model

$$p_{1,t} = \beta_o + \beta_1 p_{2,t} + \mu_t \qquad (1)$$

From the above equation, market integration requires the restriction that β_1 equal to 1. Alternatively, a less stringent definition of market integration would be to have β_1 differ from 1 but only by a small amount.

The premise behind the regressions is best explained with an illustration. Suppose there are two pipeline companies in a supply region serving a demand region. The prices in the demand region are given by:

$$P_{s1} + t_1 = P_{d1} \qquad (4.1)$$

$$P_{s2} + t_2 = P_{d2} \qquad (4.2)$$

where t_{si} is the transportation cost pipeline i charges to deliver gas to demand region j. Rearranging the two equations yields:

$$P_{s1} = t_2 - t_1 + P_{d1} - P_{d2} + P_{s2} \qquad (4.3)$$

From this equation, an empirical test can be conducted in the form of:

$$P_{s1} = \alpha + \beta P_{s2} \qquad (4.4)$$

This test determines whether or not the supply markets are perfectly, highly, or slightly integrated. If the price of natural gas at two separate locations is linked with one other, then a disturbance in one state will trickle over to the other state. The β correlation coefficient from the regression above would reflect any linkage between the price of gas at state i and the price at state j. On the other hand, the absence of a link between two separate markets will result in a price shock in one state having no impact in the price of another state.

The tests do not require the t_{si} and P_{di} variables as these variables are already incorporated in the intercept term. More specifically, perfect integration requires that if price in supply region 1 increases by one and the transportation cost differential between the two region remains the same, the price at region 2 should also increase by one.

The underlying stochastic process of a time series is stationary if its mean and variance are constant over time and the value of covariance between two time periods depends only on the distance or lag between the two periods and not on the actual time at which the covariance is computed.[24] A common form of a nonstationary series is a unit root problem, also known in time series as a random walk. A unit root exists if the coefficient from regressing the value of p at time t on its value at time (t-1) is found to be equal to 1. If a nonstationary time series has to be differenced d times before the differenced series is stationary, the series is integrated of order d, I (d).[25] From this, a series is then integrated of order 1, I (1), if first differencing leads to the differenced series to be stationary. A relevant concept associated with series that is integrated of order 1 is cointegration. Cointegration arises when the linear combination of two I (1) variables is stationary, I (0). In this situation, the trends in both series cancel each other out and the two variables are cointegrated.

A common test applied to find out if a series is nonstationary is the Dickey-Fuller (DF) test. This test is based on the conventionally computed t statistic, known as the DF or MacKinnon DF absolute critical τ statistic. If the computed absolute value of the τ statistic exceeds the DF critical value, then we do not reject the hypothesis that the given

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[24] Gujarati, D. (1995). *Basic Econometrics (3rd edition)*, Mc-Graw Hill Inc.p.713.
[25] *Ibid.*,p.719.

time series is stationary.[26] Conversely, if the computed absolute value is less than the DF critical value, then the series is said to be nonstationary. Further, a large negative τ value is generally an indication of stationarity.[27]

The regression ran by the DF test is of the form:

$$\Delta p_t = \delta p_{t-1} + \mu_t \qquad (4.5)$$

The null hypothesis for the DF test is that $\delta = 0$, suggesting that the series exhibits a unit root. A constant term and/or a trend term can also be included in the above regression.

De Vany and Walls (1994) and (1996) have tested equation (4.4) using gas spot market price series from 1990 – 1993. "Perfect market integration requires that the estimated cointegrating parameter, β, in the cointegrating regression be equal to one."[28] Although the contribution of this chapter is largely based on this framework, other relevant explanatory variables are also incorporated in the model. Along with prices, the number of pipelines serving a particular geographic region was also generated and included in the regression. A trend variable was also included to capture the effect of time on prices. The model to be estimated is of the form

$$P_{s1} = \alpha + \beta_1 P_{s2} + \beta_2 num + \beta_3 t \qquad (4.6)$$

[26] Gujarati, D. (1995). *Basic Econometrics (3rd edition)*, Mc-Graw Hill Inc. p.719.
[27] *Ibid.*, Footnote 11 p.719.
[28] Walls D. (1993). "Pipeline Access and Market Integration in the Natural Gas Industry:Evidence from Cointegration Tests". *The Energy Journal* 14 (4):7.

Spatially separate markets are integrated "when the pattern of prices is such that there exist no profitable arbitrage opportunities".[29] The intuition behind this model is that if the two separate spot markets are linked together, a price series in one market, p_j, will be a good predictor of the price series in another market, p_i. This is because arbitrageurs would ensure that the difference in prices between two markets is bound by the transportation and transaction costs of moving the gas between the two markets.

If the price series are not stationary, one determines whether there exists a linear combination such that the errors from the two series are stationary. If this is the case, then the two series are cointegrated or drawn from the same market. However, integration requires that the estimated cointegrating parameter also be equal to one or close to 1. Since the standard *t* test based on asymptotical distribution, is not applicable to nonstationary series, Johansen's (1998,1991) procedure should be used. This is because his method "allows general linear restrictions on the cointegrating parameters to be tested using a likelihood ratio test".[30]

4.2 Data and Methodology

The data consists of daily observations of natural gas spot prices for the years 1993 – 2001. Prices at eighty-seven nodes throughout the U.S. were obtained from the *Gas Daily*, an industry periodical. The nodes are located within twelve geographic regions: West Texas – Waha, East Texas – Carthage, Texas East – Houston Katy, Texas

[29] Walls, D. (1994). "A Cointegration Rank Test of Market Linkages with an Application to the U.S. Natural Gas Industry." *Review of Industrial Organization* 1994 (9):181.
[30] *Ibid.*,p. 184.

North – Texas Panhandle, Texas South – Corpus Christi, Louisiana – Onshore South, Oklahoma, New Mexico – San Juan Basin, Rockies, Canadian Gas, Appalachia, and Mississippi/Alabama. A variable representing the number of pipeline companies for each region at any given time was also generated.

Eighty-seven spot markets are represented in the data and Table 4.3 lists the markets where prices were included by geographic region and by company. Prices are in dollar per unit of thermal energy, ($/MMBtu). Since the data consists of a large set of price series, the ANR pipeline at the Louisiana Onshore region, which is a major hub of the pipeline network, was chosen to be the benchmark company for comparison.

TABLE 4. 1 - DESCRIPTIONS OF VARIABLES USED IN THE ECONOMETRIC ANALYSIS

Variable	Description
Price Series	Natural gas spot price for eighty-six nodes, not including the spot price for ANR at Louisiana, at twelve geographic regions.
Anr_la	Spot price of ANR at Louisiana Onshore– Benchmark Pipeline
Comp	Number of pipelines serving the geographic region
Time	Time trend – daily from 1993 – 2001.
Dreg*Time	Time trend – daily from 1994 – 2001.
Note: Data are for 1993 – 2001 unless indicated otherwise.	

4.3 Regression

Table 4.1 offers a description of the variables used in the regression and discussed in the theory section above. Table 4.2 specifies the expected signs, mean, and standard deviation of the variables used. If the price series is nonstationary, "Engle and Granger show that the least squares estimator of the cointegrating parameter is consistent but its estimated standard error is not."[31] Hence, the presence of a unit root in the price series is

[31] Walls D. (1993). "Pipeline Access and Market Integration in the Natural Gas Industry:Evidence from Cointegration Tests". *The Energy Journal* 14 (4),p7.

tested for using the statistical test developed by Dickey-Fuller (1979). The Dickey-Fuller test regresses the first differences of the price series on a lagged value of the price level.

TABLE 4.2 – EXPECTED SIGNS AND DESCRIPTIVE STATISTICS OF THE PRICE SERIES

Price Series	Expected Sign	Mean	Std. Dev.
Spot price at each node	Dependent	2.55	1.41
ANR (benchmark node)	+	2.63	1.33
Num competitors	-	8.64	3.27
Time trend	+	1455.31	842.35

The data is estimated by using least-squares regression. Since nonstationarity invalidates standard statistical inferences, the price series in the data are tested for stationarity using the Dickey-Fuller and Augmented Dickey-Fuller tests.[32] Since the asymptotic distribution theory used in building the usual *t*-test statistic is only valid when the data are stationary, the price series data were first tested for the presence of a unit root. If the price series data are non-stationary, special cointegration methods such as those developed by Granger (1986), Engle and Granger (1987), Johansen (1988, 1991), and Johansen and Juselius (1990) have to be used in estimating the parameter restrictions of the regression.

To test for unit root, each price series is tested using the Dickey-Fuller (DF) test. Various Augmented Dickey-Fuller tests were also run and Table 4.3 shows the results from these tests. The null hypothesis that a unit root exists is rejected except for fifteen price series out of the eighty-seven included. Further, each price series is pooled and

[32] Cointegration methods are applicable for nonstationary series because it allows "estimating and making inference on long-run equilibrium relationships in the presence of short-run fluctuations." See Walls (1995) p.6.

tested for unit root using the DF test, given by the t-statistic for δ in Equation (4.5) where Δ is the difference operator.

$$\Delta p_t = \delta p_{t-1} + \mu_t \qquad (4.7)$$

TABLE 4.3 - DICKEY-FULLER & AUGMENTED DICKEY-FULLER TESTS

Region	**Pipeline Company**	**DF** *-2.86*	**ADF w/ trend constant, lag(1)** *-3.410*
Texas West – Waha	El Paso	-4.339***	-5.517***
	Northern	-4.714***	-6.742***
	Tex Intra/Hub Tailgate/Waha	-3.998***	-6.211***
	Transwestern	-4.173***	-4.396***
East Texas - Carthage	Carthage Hub Tailgate	-3.628***	-5.885***
	Koch Gateway (United)	-7.863***	-9.291***
	Lone Star	-6.930***	-7.626***
	MRT mainline	-4.100***	-6.409***
	NGPL (G8) (Midwest Gulf)	-5.896***	-7.913***
	Tennessee, 100 leg	-12.067***	-9.296***
	Texas Eastern	-3.839***	-4.015***
	Texas Gas (Zone 1)	-5.691***	-6.048***
Texas East - Houston Katy	Florida Gas	-4.874***	-7.572***
	Houston Ship Channel	-4.235***	-6.682***
	Katy Hub Tailgate	-3.997***	-6.498***
	NGPL G4 (S.Texas)	-2.087	-2.094
	Tennessee	-2.079	-2.249
	Texas Eastern (STX)	-2.071	-2.173
	Texas Intrastates	-2.392	-3.035
	Transco Z2 St. 45	-4.702***	-6.003***
	Trunkline North	-9.887***	-9.738***
Texas North - Texas Panhandle	ANR	-2.174	-2.121
	KN header	-2.965*	-4.350***
	NGPL A811 (Permian)	-9.470***	-10.022***
	Northern (Mid 10)	-6.190***	-6.992***
	PEPL	-2.25	-2.244
	Transwestern	-4.658***	-4.701***
Texas South - Corpus Christi	Agua Dulce hub	-3.994***	-6.373***
	Florida Gas	-4.887***	-5.810***
	HPL	-9.976***	-9.586***
	Koch Gateway	-7.981***	-8.588***
	MidCon Tex (UTTCO)	-6.395***	-9.189***
	NGPL G1 (S.Texas)	-4.576***	-6.159***
	Tennessee	-4.999***	-6.727***
	Texas Eastern (STX)	-3.995***	-5.173***
	Transco Z1 St 30	-4.783***	-6.701***
	Trunkline	-7.189***	-7.273***
	Valero	-14.768***	-11.586***
Louisiana – Onshore	ANR	-4.924***	-5.986***

South			
	Columbia	-5.091***	-6.664***
	FGT Z1	-4.691***	-5.637***
	Henry Hub	-5.716***	-7.410***
	HIOS	-2.181	-2.534
	Koch Gateway (United)	-4.621***	-4.700***
	La. Intrastates	-5.363***	-6.243***
	NGPL G5 (La.)	-4.879***	-6.275***
	Sonat	-4.850***	-6.248***
	Tennessee	-4.789***	-6.449***
	Texas East ELA (B)	-5.469***	-6.716***
	Texas Gas, SL	-5.127***	-6.536***
	Transco Z4 St85	-4.724***	-5.452***
	Trunkline (WLA)	-4.364***	-5.497***
Oklahoma	ANR	-4.471***	-6.099***
	El Paso	-5.410***	-9.181***
	NGPL A9 (Midcont)	-4.583***	-6.285***
	NorAm	-4.635***	-6.140***
	Northern (Mid 11)	-6.024***	-7.255***
	ONG	-3.527***	-4.447***
	PEPL	-4.682***	-6.642***
	Williams	-4.631***	-6.356***
New Mexico - San Juan Basin	El Paso (Non-Bondad)	-3.335**	-3.932**
	NW (Ignacio)	-2.720*	-3.102
	Transwestern SJ	-13.266***	-10.127***
Rockies	CIG (N. Sys.)	-3.402**	-3.940**
	D-J Basin	-5.923***	-6.274***
	Kern River	-5.219***	-5.290***
	KN Mainline (west)	-2.771*	-2.455
	Northwest Domestic	-3.368**	-3.446**
	Questar	-6.459***	-5.378***
	Cheyenne Hub	-2.253	-2.493
Canadian Gas	Iroquois	-6.629***	-6.019***
	Niagara (NFG,Tenn)	-4.438***	-5.029***
	NW-Sumas	-6.706***	-9.538***
	NOVA (AECO-C, NIT)	-2.660*	-2.678
	Parkway/Dawn	-2.124	-2.354
	PGT (Kingsgate)	-7.692***	-8.593***
	Tenn. (Niagara)/(NFG)	-2.761*	-2.603
	Viking (Emerson)	-7.776***	-5.350***
	West Coast, St2	-2.201	-2.461
	Alliance (intro interstates)	-5.201***	-5.145***
Appalachia	CNG/App(Oakford,Pa.)	-4.125***	-4.152***
	Columbia	-4.971***	-5.263***
	Dominion, North Point	-3.457***	-3.998***
MS/AL	FGT, Mobile Bay	-3.303**	-3.593**
	Koch Mobile Bay	-17.145***	-11.575***
	Gulf South, Mobile Bay	-1.979	-1.903
	Texas E. M-1 (Kosi)	-3.452***	-3.893**

***significant at the 1% level ** significant at the 5% level * significant at the 10% level

Table 4.4 reports the results of the unit root test. The null hypothesis that a unit root exists is rejected.

TABLE 4.4 – POOLED DICKEY-FULLER TEST

Variable		
Price Series	0.983	***
	(2370.3)	
Benchmark Price Series	0.984	***
	(2480.1)	
Observations	195111	
Adjusted R-square	0.969	
t-stats in parenthesis		
***significant at 1% level		
Note: Data are for 1993 – 2001 unless indicated otherwise.		

Given that δ is less than 1, each price series is pooled and paired with the benchmark pipeline in order to test for the parameter restriction of whether $\beta = 1$. If the parameter β in equation 4.4 is indeed equal to 1, then one can say that the market is perfectly cointegrated. The results from the regression including and excluding the # *competitors* variable are given in Table 4.5.

To allow for the possibility that the extent of price linkage varies among the various locations, regressions were also ran that allow for the coefficients of one pair to differ from another pair. This is captured in Runs 4 and 5; whereby the interaction of a pair dummy variable with the ANR benchmark price, $p_s D_{i,j}$, is introduced. With the differential intercept coefficient capturing the effect of how much the mean of one pair differs from another, the differential slope coefficient allows one to capture the difference between the correlation coefficient among the eighty-six price pairs.

4.4 Results

Based on the regressions described in this chapter, the null hypothesis that $\beta = 1$ is rejected at the 1% significance level. Although the β parameter suggests that the spot markets for natural gas are strongly linked together, the pipeline network does not support perfect integration, which is what was found in Walls (1994). The cointegrating parameter estimate in this model is 0.97 and is significant at the 1% level whether or not the independent variable *number of competitors* is included or excluded. This assumes that each price series pair has a common price linkage between them.

The *time trend* variable is positive and significant at the 1% level. This indicates that prices have been increasing with time. The regression also denoted a negative correlation between prices and the number of competitors. The coefficient on the variable *# competitors* is –0.0297 and is likewise significant at the 1% level. This renders a conclusion supporting the theory that competition indeed plays a role in constraining prices. The coefficient on the regulation dummy is negative 0.66 and significant in the run it was included. This indicates that prices have decreased with deregulation. The interaction variable, which interacts the benchmark price, price in ANR pipeline at Louisiana, is positive in the run where it was included and is 0.24. This denotes that prices became more linked and connected when the industry was deregulated. A partial F-test on the differential slope coefficients rejects the null hypothesis....

In the model that allows the correlation coefficient to vary from one price pair to another, the correlation coefficient on the first pair, which forms the base against which other pairs are compared to, is 0.91 and significant. Based on this regression, there are only seven differential slope coefficients that are statistically insignificant. This implies that out of the 85 state pairs, there are only seven pairs that have a similar correlation coefficient as the base pair. A partial F-test on the differential slope and intercept coefficients rejects the hypothesis that the coefficients are jointly zero. This finding supports the notion that while most price pair series are highly linked; the extent of the price correlation of one price series pair relative to another pair varies. The test also confirms that the intercept coefficient between the different price pairs vary with each other.

The deregulation time trend variable included in the regression which captures the trend in gas prices post regulation was found to be positive and significant. This denotes the probability that the price decrease post regulation may have resulted in the insolvency of some pipelines, thereby increasing pipeline concentration and prices.

TABLE 4.5 – RESULTS FROM THE REGRESSIONS

Price Series	Run 1	Run 2	Run 3	Run 4	Run 5	
ANR (benchmark n	0.9733 *** (1120.7)	0.9737 *** (1120.8)	0.7322 *** (36.9)	0.7766 *** (37.85)	0.7618 (39.04)	***
# Competitors	-0.0297 *** (-15.6)		-0.0101 *** (-5.2)	-0.0198 *** (-13.28)	-0.0198 (-13.31)	**
Time	0.0000961 *** (57.5)	0.000083 *** (57.5)	0.00012 *** (67.1)	-0.0001 *** (-2.34)		***
D_{reg}			-0.6631 *** (-16.0)	-0.4815 *** (-12.07)	-0.4981 (-12.69)	***
$P'_{ANR} * D_{reg}$			0.2368 *** (11.9)	0.1381 *** (6.94)	0.1529 (8.09)	***
D_{reg} **time*				0.00024 *** (4.91)	0.00012 (76.37)	***
F-test diff slope and intercept coefficients				F (169,195001) = 331.56 ***	F (169,195002) = 331.58	***
Observations	195,177	195,177	195,177	195,177	195,177	
Adjusted R^2	0.9027	0.9026		0.9142	0.9141	

t-stats in parenthesis
*significant at 10%, **significant at 5%, ***significant at 1%

4.5 Conclusion

The effects of the deregulation in the gas industry on natural gas prices were examined in this chapter. A number of findings were identified in this study. Firstly, Walls (1994) found that the natural gas price series used in his data were nonstationary so cointegration techniques were applied to test whether the prices are perfectly integrated or not. The series used in this chapter however, were tested for nonstationarity using the Dickey-Fuller and Augmented Dickey-Fuller test and the null hypothesis that the series exhibits nonstationary was rejected in a large majority of the series.

Secondly, relative to other studies in the gas pipeline industry, this study incorporates not only more nodes throughout the pipeline grid but a longer time frame (1993 – 2001) in its analyses as well. Since including more price series and time frame captures more information, this study is able to provide an additional contribution to the literature. Based on the data found in this chapter, the cointegrating parameter, which identifies the extent of spot price linkages between two nodes, is significantly higher than the extent of price linkages found in the previous chapter, which uses a different price series data – monthly city gate prices. Nonetheless, while empirical findings from this study suggest that the pipeline grid in both the U.S. and Canada is strongly linked with one another, prices are not perfectly integrated.

Thirdly, regressions in this chapter also relaxed the restriction that the extent of price linkage of one price series pair is the same as the linkage in another price series pair by introducing interaction dummy variables. While the empirical finding in this study supports strong price linkages among the price series pairs, this study also found that the degree to which prices are linked vary from one price series pair to another.

Fourthly, a variable is also included in the regression which captures the trend in gas prices post regulation. With this study having found lower prices during the deregulation era, there is the possibility that this price decrease have led to the bankruptcy of some pipelines thereby subsequently increasing pipeline concentration and prices. To account for this likely event, a variable that identifies whether prices post regulation has been increasing or decreasing over time is included in the regression and was found to be positive and significant in this study. This suggests that prices post regulation has been trending up and depending on what the rate of inflation is, this may imply the exercise of market power and is of interest for future studies.

Lastly, the analysis in this chapter further captures the effect of competition on the price of natural gas. Results from the analysis were able to demonstrate that prices decrease as the number of pipelines in a geographic region increases. This provides empirical support to the common notion that competition indeed leads to lower prices.

Since the analysis in this study only focuses on the gas prices seen in the primary transportation market, further improvements to this analysis should probably allow for trading of capacity which take place in the secondary markets. With this information, one can determine whether these secondary transactions have contributed towards disciplining gas prices in the primary transportation market.

CHAPTER FIVE: CONCLUSIONS

The natural gas pipeline industry witnessed significant changes to its structure in the 1980s and 1990s. Following its deregulation, a competitive gas commodity market evolved and producers and consumers no longer need to tie themselves in long-term contracts to ensure supply. This is because the spot market allowed buyers and sellers to make up for their imbalances and marginal requirements. Likewise, open access along with the unbundling of the ownership and marketing of gas from transportation services in the interstate pipeline transportation market led to a more competitive pipeline transportation market. With pipelines as contract carriers, a pipeline grid connected with the spot markets is created allowing direct exchange to take place.

This thesis has shown that the restructuring of the pipeline industry has remarkably improved the prices consumers pay in the industry. Furthermore, an extensive amount of data was collected and put together from various sources in order to carry out the empirical analysis and regressions.

This study has demonstrated that by and large, expectations of lower prices resulting from the deregulation process are attainable and reasonable. The empirical work in this paper has shown that the reliance on competitive forces to govern the industry has been a success in providing lower transmission costs and a more integrated natural gas market in the transmission of natural gas. More specifically, this study has established that while physically separate markets are not perfectly linked with each other, the markets are strongly linked and prices in one state does have a positive impact on another state. Measures of competition were also introduced in this thesis, and results from this variable have been mixed depending on which model is utilized. The models however, consistently confirmed that deregulation has lowered gas prices.

Of interest of this study is also the empirical finding that while strong price linkages among the price series pairs is supported, the degree to which prices are linked vary from one price series pair to another. Also, the gas dailies price data showed that prices post regulation era has been trending up. This highlights the possibility that subsequent to the price decrease witnessed post regulation; this might have led to the collapse of some pipelines thereby increasing pipeline concentration following deregulation relative to the regulation era and therefore increasing prices over time as well. Whether this pattern in prices persists in the near future would be of particular interest although a check against the rate of inflation and other factors such as the marginal cost of gas transportation is necessary before any definite conclusions can be drawn.

Since shippers holding firm or interruptible capacity on a pipeline has been able to trade their capacity rights on transmission pipelines with other shippers so long as all the tariff regulations are met, regulation of pipeline capacity trading in secondary markets is important. Further improvements to this study can incorporate capacity trading in the secondary markets to determine whether these transactions have contributed towards disciplining gas prices. It would be worthy to determine the percentage of current volumes shipped under a released capacity or interruptible service transaction as these compete with the regulated firm transportation pipelines offer.

Lastly, since time series data on city gate spot prices is not extensive enough thus far, it would likewise also be interesting to determine how closely these prices link with the spot market in the production fields. If it is the number of participants in the secondary transportation markets for excess spot and contract space that defines competition, this would be consistent with the findings of this thesis that suggests that it is not the number of carriers that defines competition.

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