Natural Gas Pricing in the Northeastern U.S.

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Abstract

This paper examines natural gas pricing at five citygate locations in the northeastern United States using daily and weekly price series for the years 1994-97. In particular, the effects of the natural gas price at Henry Hub, weather, and the natural gas inventory levels in the region are examined. The results indicate that natural gas spot citygate prices in the Northeastern U.S. are influenced mainly by the Henry Hub spot price and local heating degree-days. The storage-inventory level supplying the Northeast appears to have little influence.

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1. Introduction

This paper analyzes natural gas pricing behavior in the northeastern United States, where the weather-sensitive demand pattern results in highly variable natural gas citygate prices. The analyses reported here especially relate natural gas citygate prices in five locations throughout the Northeast to the price at Henry Hub, Louisiana, on the US Gulf coast—a market center with access to multiple pipeline interconnections and supplies—and to weather and storage-inventory levels. The five Northeastern locations chosen for analysis are Baltimore (Maryland), Boston (Massachusetts), Buffalo (New York State), Pittsburgh (Pennsylvania), and New York City. The techniques developed in this paper are based on correlation analyses and simple regressions, relating each pricing point to one independent variable, the Henry Hub price, on a second independent variable, weather and ending with a third independent variable, the storage-inventory level supplying the Consuming East[2]. The final result indicates the significance of each parameter influencing the pricing behavior.

In this paper, Chapter 2 introduces the Northeastern Natural Gas Market, Chapter 3 explains the data and sources used in the analyses, and Chapter 4 explains the pricing behavior. Chapter 5 summarizes this study's conclusions.

[2] Market definition American Gas Association (s. Chapter 33)

2.The Northeastern Natural-Gas Market

2.1. Demand Characteristics

The Northeast is one of the fastest-growing regions in the U.S. in terms of gas demand, with less indigenous production than any other region in North America: less than 6 percent of the region's total consumption is produced in the region. Over 60 percent of the demand in the Northeast is found in the residential and commercial sectors, compared with roughly 40 percent nationwide, resulting in a weather-sensitive demand pattern strongly dependent on the optimization of storage and pipeline capacity.

Market forces and the restructuring of the electricity sector draw attention to the significance of natural gas storage services. Buyers of gas have attempted increasingly to satisfy peak winter demands at reduced cost through strategic storage. The Pipeline Company, which formerly used storage to balance the loads of its many customers, no longer has this role; customers now make their own arrangements to store gas and move it along the pipeline systems. The lack of transportation capacity in the Northeast region in high-demand seasons promotes interactions between gas storage and capacity release.

Market centers, with their access to multiple pipeline interconnections and supplies, provide a natural platform for gas trading, risk management, and opportunities for arbitrage. Very active trading at several centers has benefited from and/or complemented growth in the natural gas futures contract market -- for instance, at the Henry Hub, New York Mercantile Exchange (NYMEX), and West Texas market center areas (Kansas City Board of Trade). More than 25 pipeline systems have access to these market centers.

The growth of market centers has created a more competitive environment for natural gas. In regional markets, gas prices signal relative demand and supply conditions, and also can indicate the degree of competition between markets. If gas markets are supported by an efficient infrastructure, such as the transmission network and institutional systems, regional demand and supply conditions will be interrelated, causing similar price movements (but not necessarily uniform price levels).

2.2.Overall Supply Situation in the Northeast

The U.S. consumption of natural gas (NG) is about 60 Bcfd (620 BCM/year), growing about 2% per year. United States production of natural gas grew at a rate of about 1% in 1997 to reach its current volume of about 52 Bcfd (538 BCM/year). Northeast consumption is now 8.4 Bcfd (87 BCM/year) -- about 14% of total U.S. consumption.

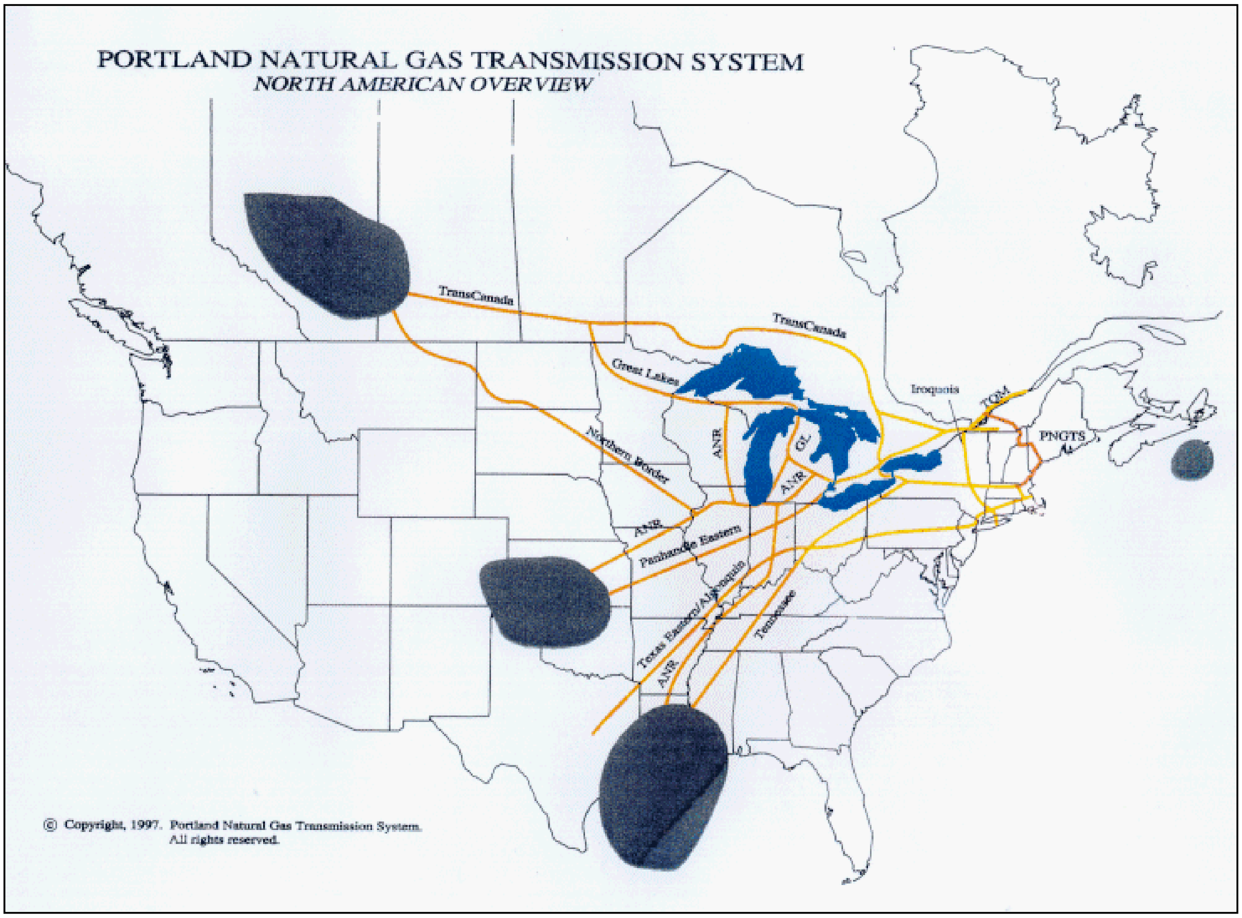
Major changes in the Northeast energy market will provide significant opportunities and risks. Substantial gas pipeline additions are proposed for the region, originating in the Midwest and Canada. The estimated cumulative Western Canadian pipeline expansions are expected to increase the total Canadian capacity to 1.3 Bcfd (13.4 BCM/yr) in November '98, 1.6 Bcfd (16.54 BCM/yr) in November 1999, and 2.9 Bcfd (30 BCM/yr) by November 2000. Key uncertainties will be available supplies from Canada and the Gulf of Mexico.

If a shortfall of Western Canadian production occurs as expected, the new pipeline couldn't be filled with gas. Higher Canadian prices will lower the value of Canadian pipeline capacity to the Northeast in the near term, possibly delaying some pipeline projects. The Gulf coast is expected to be a major source of the U.S. supply -- with increasing skepticism, however: some projects have yielded lower volumes than expected, and others have been delayed. Those customers with contracts for existing pipeline capacity will have to decide whether to extend their contracts or release capacity. If Gulf Coast supplies do not grow sufficiently, East Coast pipelines will lose value.

As a result of nuclear problems and retail deregulation in the electricity market, over 10,000 megawatts (MW) of combined-cycle facilities are in various stages of development in the New England market. New power-plant developers must decide how to purchase natural gas, as well as settle terms and conditions and determine which pipeline to use. Understanding the availability of pipeline capacity and the competitive cost of gas supply at alternative supply sources will be the key inputs in these decisions.[3]

[3] WEFA presentation at the New England Chapter, May 1998.

Figure 1. Natural-Gas Supply to the Northeast.



Demand for natural gas in the Northeast is mainly supplied by the Gulf Coast Basin, the East Texas Basin, the Illinois Basin, the Michigan Basin, and the Canadian supply from the Western Canada Sedimentary Basin (**Fig. 1**). Several transportation expansions in the Northeast Region are planned. Of 26 projects planned within a region representing 2,310 MMcfd (24 BCM/yr) of new capacity, 17 are either directly or indirectly linked by mutual service needs or partnerships. These 17 projects constitute about 50 percent of the new capacity additions in the region, or 1,115 MMcfd (12 BCM/yr).

2.3.The Natural Gas Transportation System in the Northeast

The main pipeline companies serving the Northeast natural gas market are shown in **Figure 2**. The main stream of the natural gas supply flows from the southern to the northern part of the region (**Fig. 3**).

Figure 2. Map of the Northeastern Natural-Gas Market.

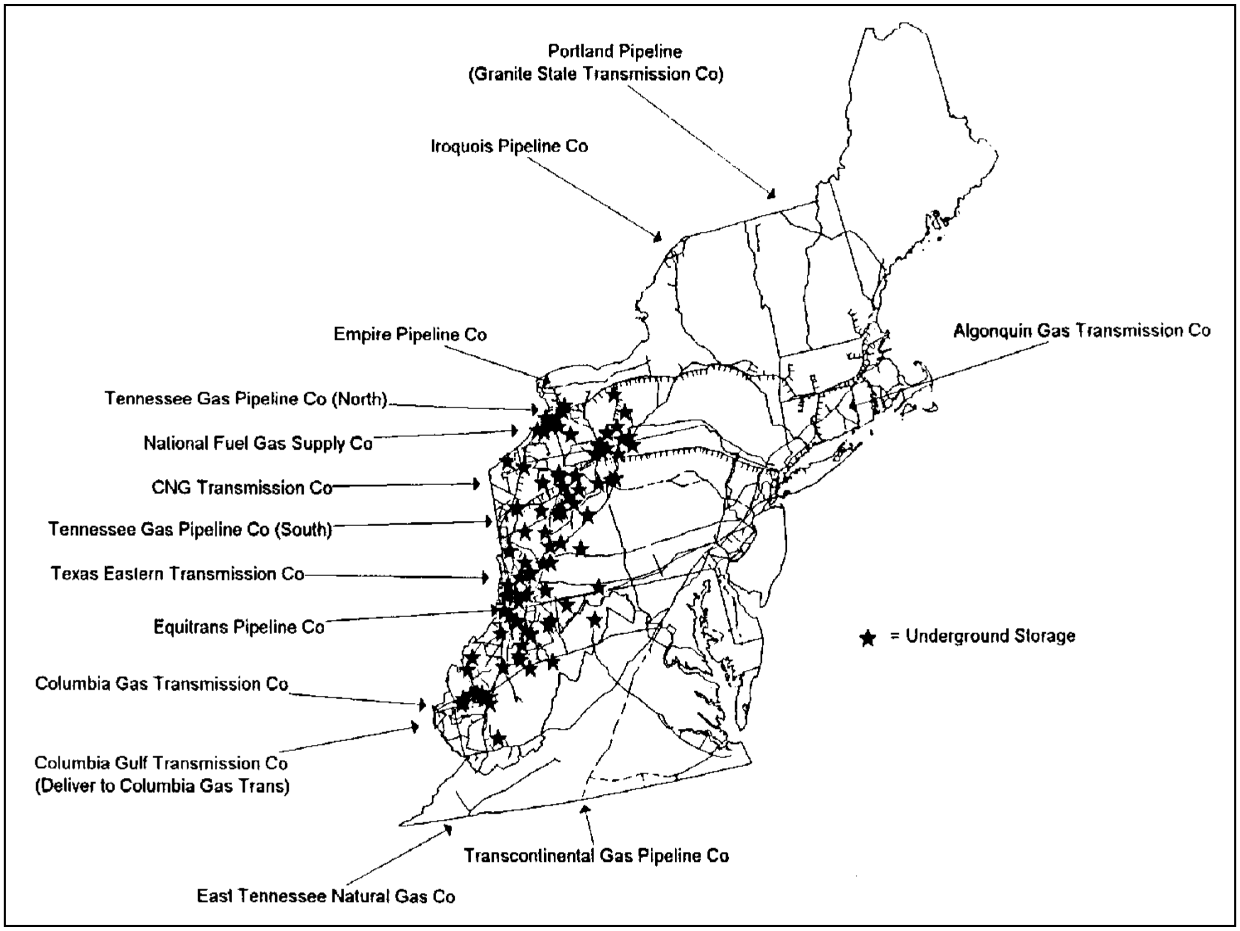
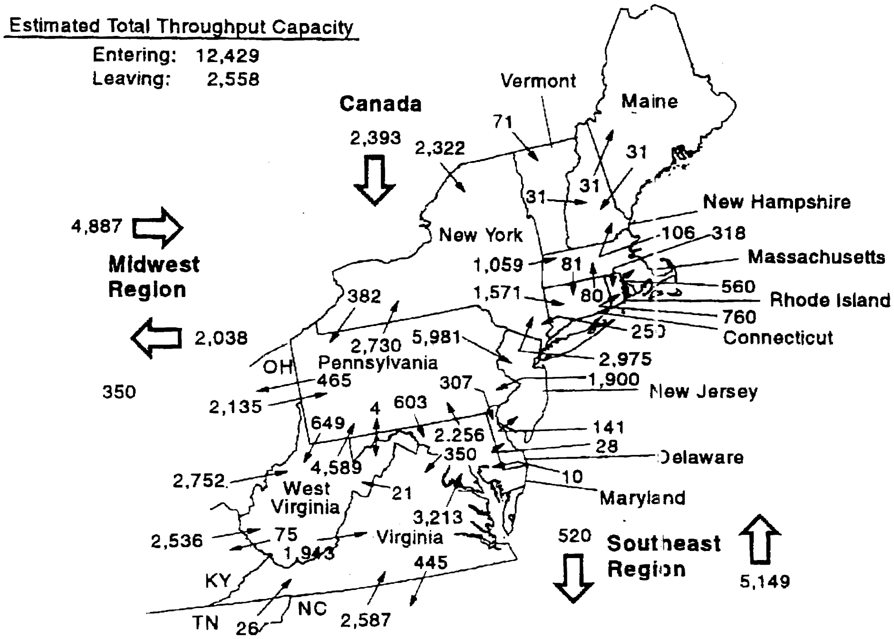


Figure 3. Interstate Natural Gas Capacity Summary for the Northeast Region, 1996[4]



Principal Interstate Natural Gas Pipeline Companies Operating in the Northeast Region

Principal Market Region / Pipeline Name	Regional Supply Source(s)	Primary/ Secondary System Configuration[2]	Regional Service Level: Percent of System Peak-day Deliveries[3]	Regional Service Level: Number of Delivery Points	Regional Service Level: Number of Intercon-nects	Systemwide Utilization Rates[1] %: 12-Month Average[4]	Systemwide Utilization Rates[1] %: Peak Day[5]	Systemwide Utilization Rates[1] %: Summer Offpeak[6]
Regional Pipelines								
Algonquin Gas Transmission Co	SW	Trunk/Grid	100	97	5	72	89	45
CNG Transmission Corp	SW, NE	Grid	87	110	25	80	92	25
Columbia Gas Transmission Co	SW, NE	Grid	51	293	16	73	98	26
Eastern Shore Natural Gas Co	SW	Grid/Trunk	100	NA	NA	NA	NA	NA
Equitrans Inc	SW, NE	Grid	100	132	10	70	78	23
Granite State Gas Transmission Co	Canada	Grid/Trunk	100	NA	NA	NA	NA	NA
Iroquois Gas Transmission Co	Canada	Trunk	100	10	4	102	122	99
National Fuel Gas Supply Corp	SW, Canada	Grid/Trunk	100	98	3	75	92	29
Tennessee Gas Pipeline Co	SW, Canada	Trunk	55	116	51	90	111	70
Texas Eastern Transmission Corp	SW	Trunk	88	69	18	84	109	49
Transcontinental Gas Pipeline Co	SW	Trunk	69	124	10	83	99	81
Vermont Gas Systems Inc	Canada	Trunk	100	NA	NA	NA	NA	NA
Supplemental Pipeline Service								
East Tennessee Natural Gas Co	SW	Trunk/Grid	8	25	0	84	88	37

[4] Volumes in Million Cubic Feet per Day

2.4. Natural Gas Storage in the U.S.

At the beginning of 1997, at least 410 underground storage facilities were in operation in the United States, providing almost 3.8 Tcf[5] (106 BCM) of working gas capacity. The 410 operating storage sites consist of 342 depleted fields (representing about 88% of total U.S. working gas capacity and 74 percent of total deliverability), 40 aquifer reservoirs (about 9 % of total U.S. working gas capacity and 11 percent of total deliverability), and 27 salt cavern facilities (only 3 % of total U.S. working gas capacity but nearly 15 % of total deliverability). The maximum deliverability is the maximum daily volume of gas (Mcf/d) that can be delivered using currently available facilities (wells, pipeline, compression, and metering) when the reservoir is at its maximum volume. Deliverability declines as gas is withdrawn from a reservoir.

The state of Michigan ranks first, with 47 storage facilities both in terms of total U.S. working gas capacity and total deliverability, followed close by Texas with 35 storage sites. Pennsylvania has the greatest number of storage sites (60), ranking third in both working gas capacity and deliverability. The Northeast Region -- with significant storage assets in Pennsylvania, West Virginia, and, to a lesser extent, New York -- ranks third, with total U.S. working-gas capacity of 18% and 16% of total deliverability.[6] A large number of storage projects are planned for the Northeast, where natural gas is generally stored in depleted gas/oil fields. Of the 27 U.S. planned salt-cavern projects, 11 are in the Northeast, representing 32% of planned additions to increase deliverability.

Underground storage in the United States has historically served a variety of operational needs for pipeline companies, producers, distributors, and end users. One of the primary uses has been to enhance the seasonal deliverability of mainline transmission capacity. In the market, area storage also serves as a backup supply in the event wellhead production is interrupted (*e.g.*, as a result of a hurricane or well freezup). In production areas, underground storage can also be used to balance the load of daily throughput on pipelines in order to prevent operational problems associated with high or low levels of “line pack” (gas stored in the pipeline), or to level wellhead production and hedge seasonal differences in wellhead prices.

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[5] Trillion Cubic Feet

[6] Source: *EIA/Natural Gas Monthly*, September 1997.

Traditionally, these services or applications for underground storage have been met through the use of baseload storage facilities, developed primarily in depleted gas and oil fields, with large working gas capacities and relatively long (60 to 100 days) withdrawal cycles. Most have been designed with injection cycles in the range of 200 days, with the intent of refilling storage during summer months. Pipeline capacity was generally constructed along with new storage capacity in order to assure adequate downstream deliverability of the storage gas during the peak winter periods. Much of the United States' existing storage capacity, particularly in the major market areas of the Northeast and Midwest, was designed and built by interstate pipeline companies for such service.

Order 636 (the "restructuring rule" issued by the Federal Energy Regulatory Commission (FERC) in April 1992) and different supply and demand conditions have required market participants to explore new approaches to the use of storage facilities, develop new services, and propose substantial additions to existing storage capacity. Supplemental storage facilities' characteristics differ from baseload storage facilities'; for example, their withdrawal periods are shorter, ranging from 10 to 15 days. Independent developers are also more likely to sponsor such facilities than are interstate pipeline companies, and contractual practices within the gas industry have changed. For example, orders provisions for unbundling, no-notice sales service, and rate design are most important for underground storage.

"No-notice service" is essentially a deluxe firm-transportation (FT) service. The main difference between no-notice and more generic FT service is that under FT, if a shipper takes an amount of gas that exceeds scheduling limits established for a specific time period with the pipeline company, then the shipper may incur penalties. Under no-notice service, a shipper may exceed these scheduling limits without incurring daily scheduling penalties. To provide the service, a pipeline company may use pipeline-owned storage, borrow gas from contract storage, or allow gas scheduled for interruptible customers to be delivered to firm customers.[7]

[7] Energy Information Administration, Office of Oil and Gas.

In coming years, significant growth in natural-gas demand is expected as new gas-fired electric power plants begin operations. In the near future, 4000 MW of nuclear power capacity will be decommissioned, most of it to be substituted by Combined Cycle Power Plants. In addition to traditional seasonal storage service, storage is used for supply balancing close to power plants, emergency backup service, no-notice service (for firm delivery of the difference between a customer's daily nomination and what the customer actually requires on a day), and price hedging. These services require significantly more operational flexibility than can be provided by traditional seasonal supply service. Storage will also continue to be marketed as a potential price arbitrage and hedging tool.

2.5. Changes in Use of Transportation and Storage

Shippers in today's natural-gas market are increasingly pressured to manage their gas supply and transportation portfolios efficiently to reduce costs. When possible, they are choosing some of the new services that compete with primary firm transportation services offered by interstate pipeline companies, such as high-deliverability storage, "high-quality" interruptible capacity, released capacity.

Order 636 converted the firm sales *entitlements* of pipeline companies' customers to firm transportation *rights*, providing customers little opportunity to reduce their firm commitment levels. With the changes in rate design, development of new services, and new-found capabilities to identify the cost of each natural-gas service component, customers are finding that long-term contracts entered into years earlier may no longer reflect current market conditions.

Firm transportation has also become more expensive for some shippers because of the current rate structure. Order 636 changed the way rates are calculated by requiring pipeline companies to use the straight fixed-variable rate design, which increases the cost of reserving capacity but lowers the variable cost of gas transported. Shippers whose peak-period needs for capacity are very high compared with their average needs are particularly affected by this change. [8]

[8] For Transportation Rate Structure, see Appendix E.

Technology has allowed many companies to reduce the amount of working gas they keep in storage (especially relative to current demand) at any point in time without compromising deliverability. This change in industry practice increases price uncertainty during periods of consistently colder-than-normal temperatures. However, increased use of salt storage and new technologies (such as horizontal wells in conventional oil- and gas-storage reservoirs) enable the industry to bring more incremental supplies of gas to market sooner than in the past. The industry is also able to reduce price risk through the use of futures contracts and other financial instruments.

3. Data, Sources, and Tools

3.1. Natural Gas Prices

The empirical work in this study is based on daily spot prices from 1994 through 1997 at five Northeastern locations—New York, Boston, Baltimore, Pittsburgh and Buffalo (**Fig. 4**)—and at Henry Hub, the major transportation hub and pricing point for natural gas supplies from the Gulf and Mexico and the Southwest. The prices for Henry Hub were taken from "Gas Daily Historical Prices," published by Pasha Publications. The "citygate" prices were provided by "Bloomberg Energy" (New York), which provides online coverage of the spot and futures markets for energy, updated throughout the day in addition to historical spot citygate prices back to 1994. These citygate prices include the premium paid for delivery to the citygate from the market center, the "pricing point," where incoming gas from major transmission lines is channeled to smaller distribution lines.

Figure 4. Map of the Northeast.

The five locations in the Northeastern U.S. were chosen because of their positions in this regional market. New York is the largest demand center, and Boston is the location farthest from the sources of gas in the Gulf of Mexico or Canada. The other three cities are also major demand centers, but they are closer to the sources of supply and to other regional markets. Baltimore and Buffalo lie astride the major pipeline routes into the Northeast from the Gulf and Canada, respectively. Pittsburgh is located along the other major pipeline route into the Northeast from the Gulf, and it lies midway between the Northeast and the competing Midwestern market, which is similarly supplied by supplies from the Gulf of Mexico and Canada.

3.2 Heating Degree-days

The temperature-related unit of measure used for this analysis is the *heating degree-day*, which is the difference between the average of a day's high and low temperatures and the reference temperature (65^{o} F.), when the average is lower than the reference. This measure indicates the relative amount of heating demand, so that on a day with "20 degree-days" twice as much heating demand would be expected as on a day with "10 degree-days".[9] Daily heating degree-day data for 1994 through 1997 were obtained for the five citygate locations, Baltimore, Boston, Buffalo, Pittsburgh, and New York City, from Cornell University's Northeast Regional Climate Center. The same source also provided reference "normal" temperatures (the average temperature for each day over the past 30 years) for the same locations.

3.3. Natural Gas Storage

Data on natural gas storage is obtained from the American Gas Association (AGA)'s "Weekly Storage Report," which is currently the most reliable source available. This report is based on the AGA's Weekly Underground Gas Storage Survey, whichcollects weekly inventory levels from operators of underground storage facilities that are members of the AGA. The U.S. is sectioned into three regions—the Producing Region, the Consuming East, and the Consuming West—taking into account climate, population density, and gas production and demand. For the present study, the weekly average storage levels for the Consuming East from 1994 through 1997 are

[9] (*Cooling degree-days* are similarly derived as the difference between the same average and the reference temperature, when the average is above the reference.)

used. To relate the weekly natural-gas storage inventory data to daily natural-gas spot prices and heating-degree days, weekly averages were formed for the latter two data series.

4. Explanation of Pricing Behavior

4.1. Statistical Definition of a Market

The conventional definition of a market is adopted for this study. Accordingly, a market for a good is defined as the area within which the price of the good tends toward uniformity, allowance being made for transportation costs.[10] These conditions are not met exactly in real markets: prices in two places seldom differ by exactly "the" transportation cost, for several reasons. No unique transportation cost may exist; the costs of movement may be less for some buyers than it is for others; or the total cost of transportation, including transaction costs, may be influenced by (among other things) shipment size. Stochastic shocks to supply and demand may also create divergent price movements in parts of a market; but, these divergent price movements are usually limited in size and duration because of the possibilities of corrective movements of goods or buyers. Thus, if we observe closely parallel price movements, the loci of the price are in the same market. If we find significant nonparallel price movements, the loci of the price are not in the same market unless the discordance in movements can be traced to changes in transportation costs.

4.2. Natural Gas Spot Citygate Prices in the Northeast

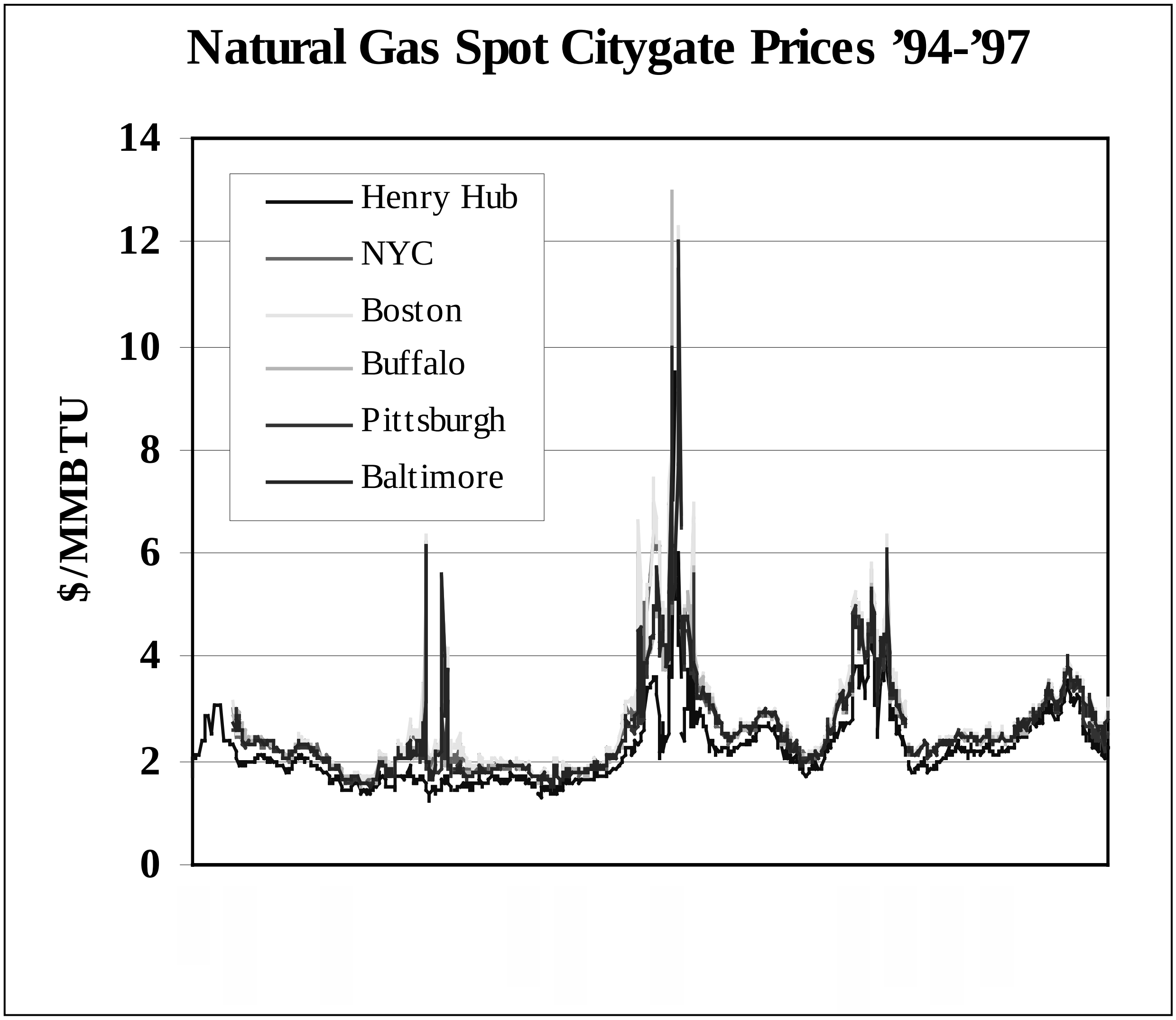
4.2.1 The Northeastern Market and the Relation to Henry Hub

Figure 5 shows the similarity of price movements among the five Northeastern locations and of those locations with Henry Hub,

[10] This is the fundamental definition of Cournot and, following him, Marshall, who states the rule:
"Thus the more nearly perfect a market is, the stronger is the tendency for the same price to be paid for the same thing at the same time in all parts of the market." (A. Marshall, *Principles of Economics*, p. 325) Source: George J. Stigler and Roberta A.Sherwin, *The Journal of Law and Economics*.

a major pipeline hub and pricing point in Louisiana. **Table 1** provides the correlation coefficients for each of these pricing points for daily prices over the four-year period, 1994-97.

Figure 5. Natural Gas Spot Citygate Prices, 1994-97.



Data Source: Bloomberg Energy.

The price at Henry Hub is typically a little lower than the Northeastern citygate prices, but it is clear that a high degree of correlation exists between the Henry Hub and citygate prices.

Table 1. Price correlation between Henry Hub and the five main natural gas citygates pricing points in the Northeast between 1994 and 1997.

Number of observations = 953.

	Henry Hub	*New York Citygate*	*Boston Citygate*	*Buffalo Citygate*	*Pittsburgh Citygate*	*Baltimore Citygate*
Henry Hub	1.000					
NY Citygate	0.8320	1.000				
Boston Citygate	0.8310	**0.9938**	1.000			
Buffalo Citygate	0.8946	**0.9503**	**0.9521**	1.000		
Pittsburgh	0.8694	**0.9653**	**0.9635**	**0.9771**	1.000	
Baltimore Citygate	0.8563	**0.9746**	**0.9733**	**0.9605**	**0.9818**	1.000

Table 1 shows a very high correlation between northeastern citygate prices -- 0.95 or better (bold numbers) -- while the correlation between prices at the Henry Hub and those at the northeastern pricing points is still high but not as strong: 0.83-0.89.

Simple regression analysis was performed on the relationshipbetween the price at Henry Hub and the five Northeastern citygate prices, using daily prices of the 1994-97 period. Ordinary least squares (OLS) regression is used using the following equation and definitions.

$$P_i = \alpha_\iota + \beta_\iota P_{HH} + \varepsilon$$

P_i= Price at Northeastern Citygate
α_ι= Constant
$\beta_\iota P_{HH}$= Coefficient on the Price at Henry Hub
ε = Regression Error

This model posits that the price in the Northeastern location depends upon the price at the principal supply point, Henry Hub. A specific interpretation might be that the price in the Northeast would tend to reflect the price at Henry Hub plus some constant reflecting transportation cost, in which case the constant would be positive and significantly different from zero and the coefficient on the Henry Hub price would be unity. As a first step, we shall test this simple hypothesis which would correspond to a completely regulated pipeline charging a non-varying fixed fee for transportation.

The regression results for New York are given in **Table 2.1**; and the data points and predicted relationships are presented graphically in **Figure 6**. A reasonable R^2 value is obtained; and the estimated coefficients for both the constant term and the price at Henry Hub are significantly different that zero at the 95% confidence level. The coefficient on the Henry Hub price is, however, also significantly different from unity; and it is clear from the Figure 6 that the slope would be much higher but for the three outliers, when the price at Henry Hub exceeded $8/mcf.

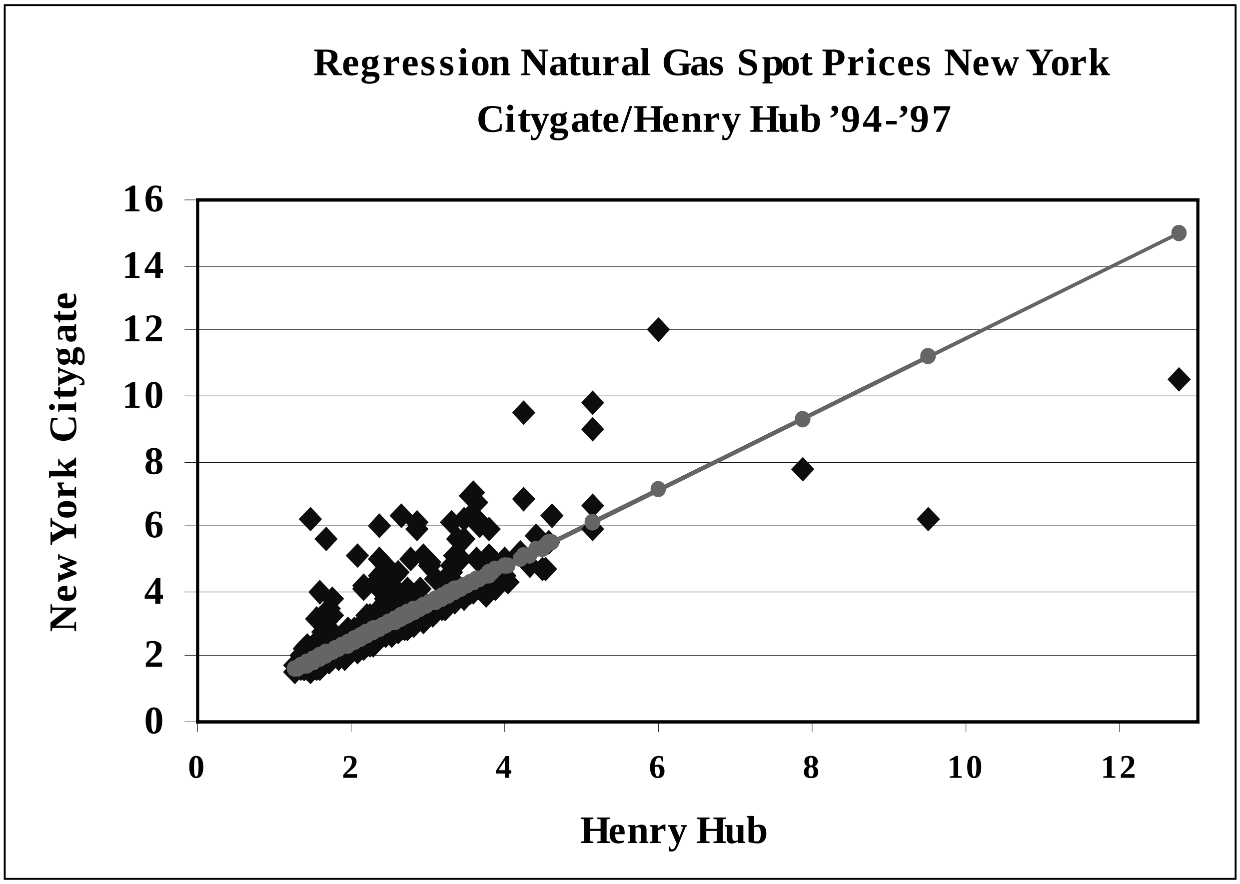
Table 2.1. Regression of New York Citygate price with one independent variable.
Number of Observations = 967 (for all regressions).
R-squared = 0.6961

NYC	Coefficient	Std. Error	*t*- statistic*
Henry Hub	1.1653	0.0247844	47.016 (6.67)
Constant	0.1262	0.0578384	2.182

* T-statistic is parentheses is the test of β=1.0.

$$\mathbf{P_{NYC} = 12.6\ cents/MMBTU + 1.1653 * P_{HH}}$$

Figure 6. Regression Graph: New York City Spot Price *vs.* Henry Hub Spot Price.



The regression results for the same specification applied to the other four Northeastern locations are provided in **Tables 2.2-2.5** below.

Table 2.2. Regression of Boston citygate price with one independent variable.

Adj R-squared = 0.6930

Boston City Gate	Coefficient	Std. Error	t-statistics*
Henry Hub	1.216667	.0260462	46.712 (8.33)
Constant	.100663	.0607831	1.656

* T-statistic is parentheses is the test of β=1.0.

Table 2.3. Regression of Buffalo citygate price with one independent variable.

Adj R-squared = 0.8005

Buffalo City Gate	Coefficient	Std. Error	t-statistics*
Henry Hub	1.0996	.0177732	61.854 (5.60)
Constant	.17654	.0414823	4.266

* T-statistic is parentheses is the test of β=1.0.

Table 2.4. Regression of Pittsburgh citygate price with one independent variable.

Adj R-squared = 0.7562

Pittsburgh City Gate	Coefficient	Std. Error	t- statistics*
Henry Hub	1.0483	.019276	54.381 (2.50)
Constant	.26678	.044991	5.930

* T-statistic is parentheses is the test of β=1.0.

Table 2.5. Regression of Baltimore citygate price with one independent variable.

Adj R-squared = 0.7335

Baltimore City Gate	Coefficient	Std. Error	t- statistics*
Henry Hub	1.07336	.0209538	51.225 (3.50)
Constant	.24507	.0489057	5.011

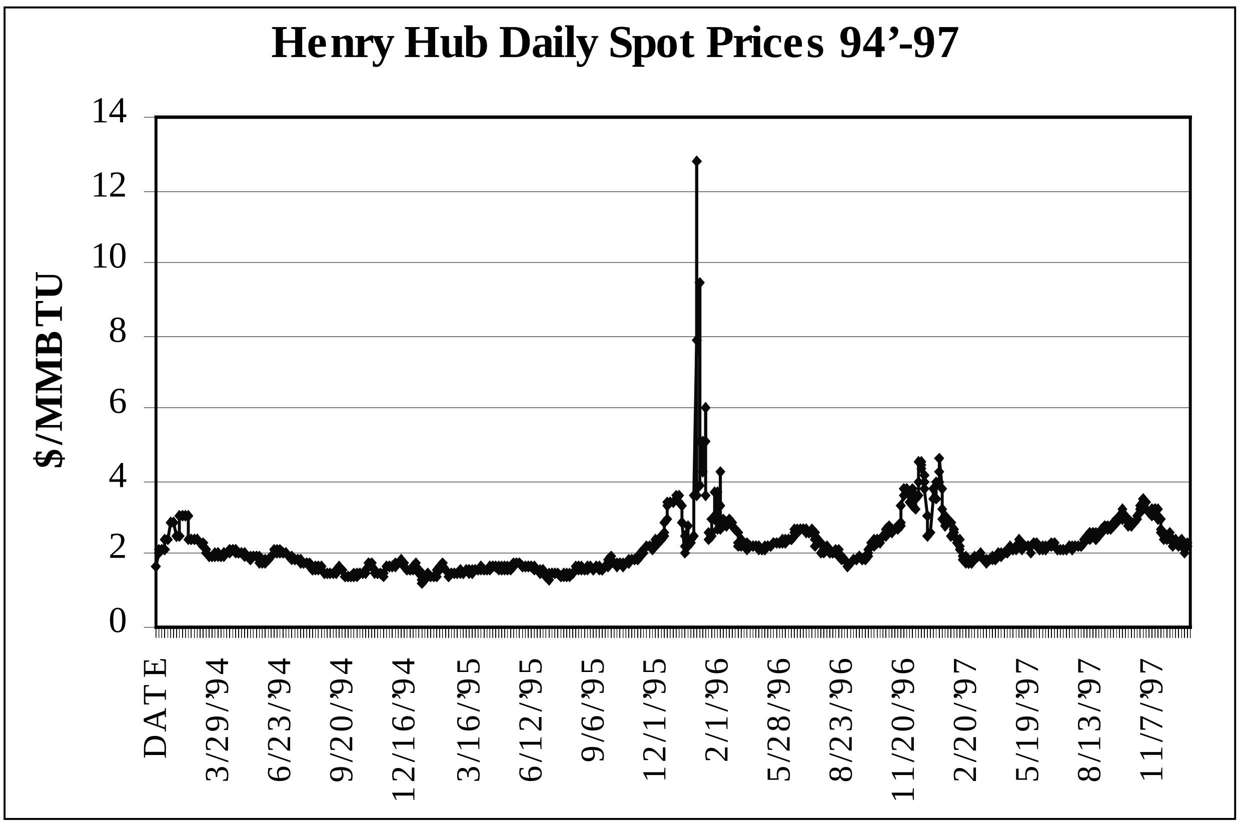
* T-statistic is parentheses is the test of β=1.0.

As was the case for New York, the price at Henry Hub appears to have a significant influence on the price of natural gas at the Northeastern locations, but the simple hypothesis of the price at Henry Hub plus a constant transportation term is rejected. Although the constant is positive at all locations, and significantly different from zero at four, the coefficient on the Henry Hub price is significantly different from unity at every location. This coefficient is always greater than one, indicating that there is something else. Before testing the likely explanation, weather, a few comments on weather-related volatility is warranted.

4.2.2. Volatility of Henry Hub and Northeastern Natural Gas Prices

As indicated by **Figure 7**, phenomenal short-term price volatility is observed occasionally in the natural gas marketplace. In general, greater volatility is observed in the winter, although the 1994-95 heating season was an exception. The following winter witnessed spectacular volatility. On February 2, 1996, for instance, buyers paid nearly 13 $/MMBTU at Henry Hub—almost six times the average price of 2.20 $/MMBTU at Henry Hub during these four-years. Temperatures during the first half of February 1996 were colder than normal, and low storage levels in the East raised concerns about supply deliverability.

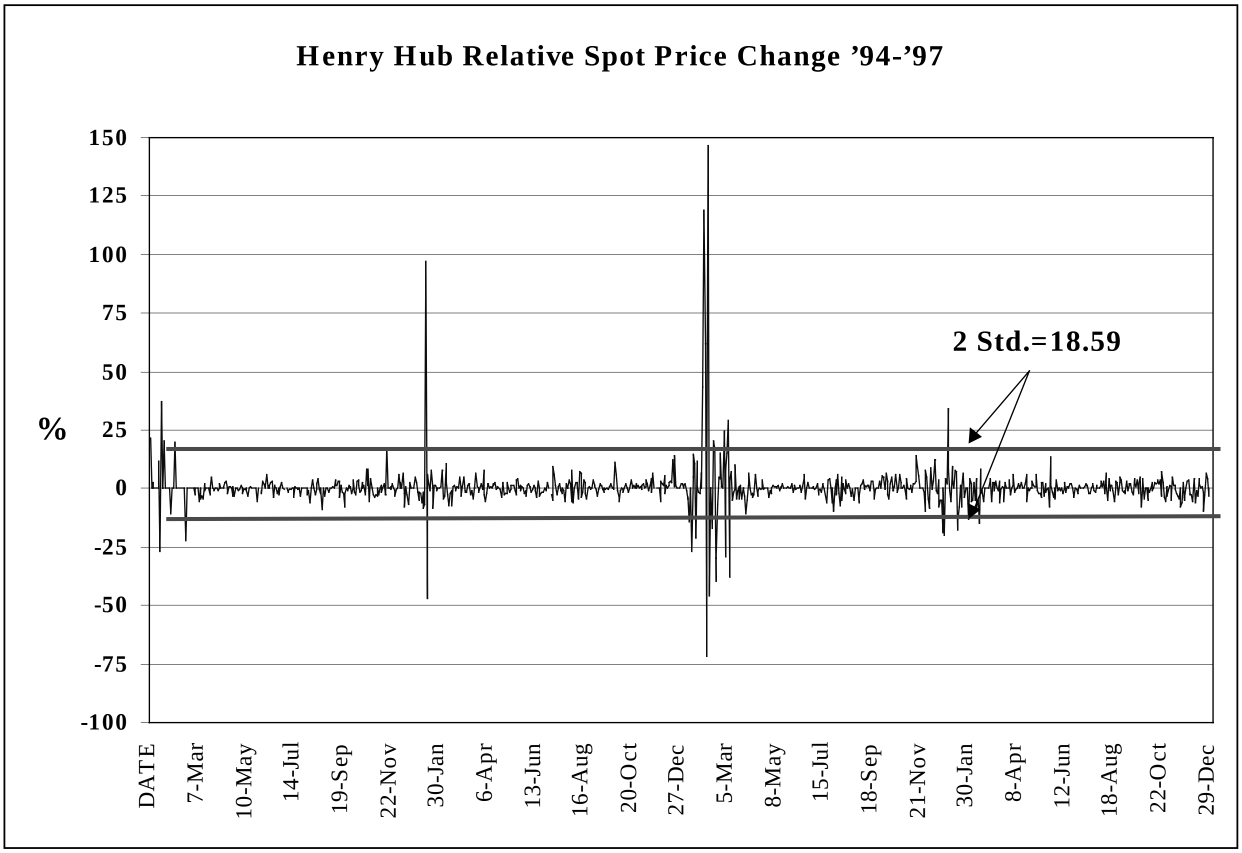
Figure 7. Henry Hub Daily Spot Prices, 1994-97.



Data Source: Bloomberg Energy.

The pattern of moderate volatility punctuated by increased and sometimes extreme volatility during the heating season is shown in **Figure 8**, which gives the percentage day-to-day change of Henry Hub prices during the last four years in relation to two standard deviations.

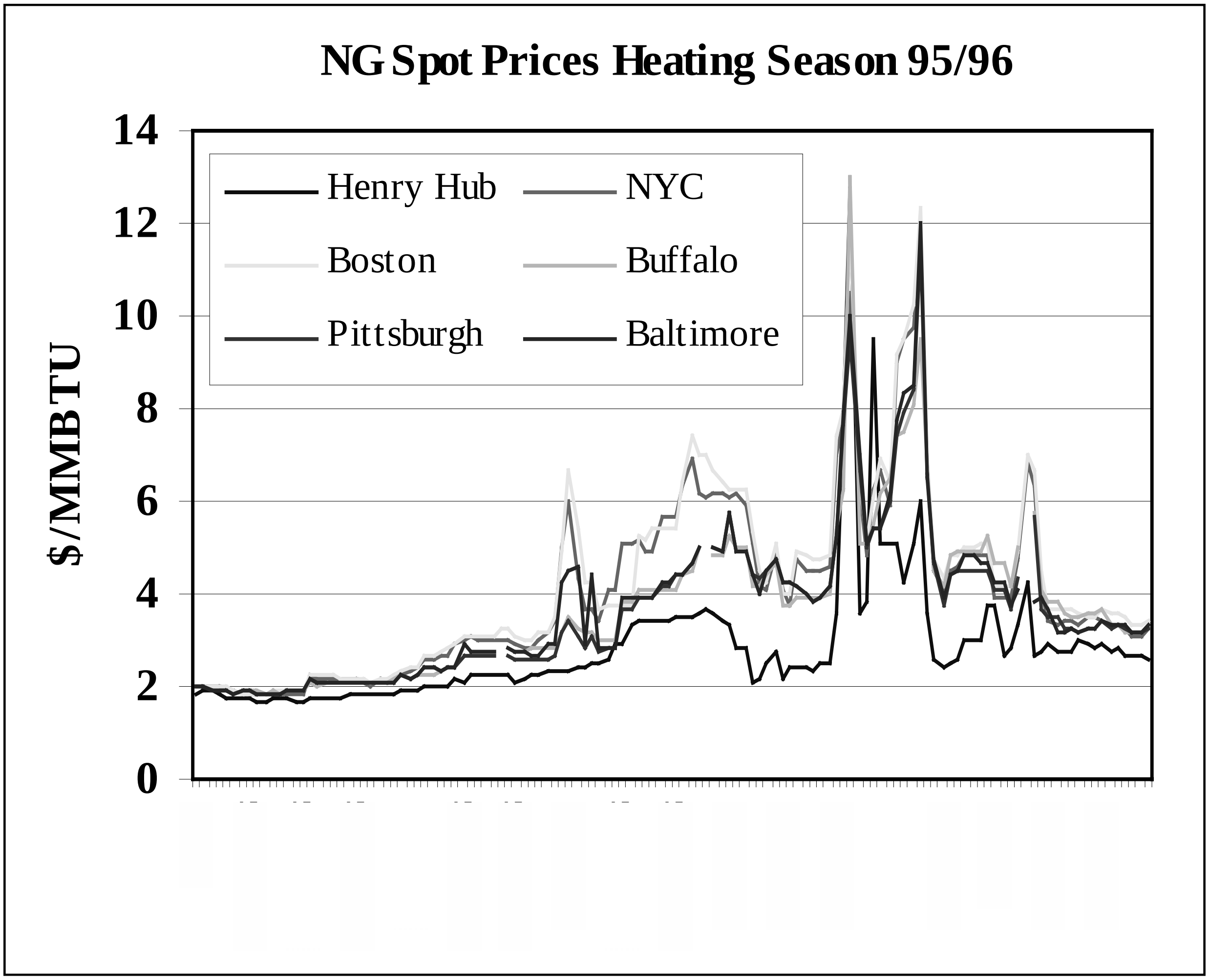
Figure 8. Henry Hub Relative Daily Spot Price Change, 1994-97.



Data Source: Bloomberg Energy.

To follow the winter pricing pattern more closely, we focus in **Figure 9** on the ’95-’96 heating season, when prices were especially volatile. Prices moved together until December ’95; turbulence started between January and February, when temperatures were colder than normal.

Figure 9. Natural-Gas Spot Prices, '95-'96 Heating Season.



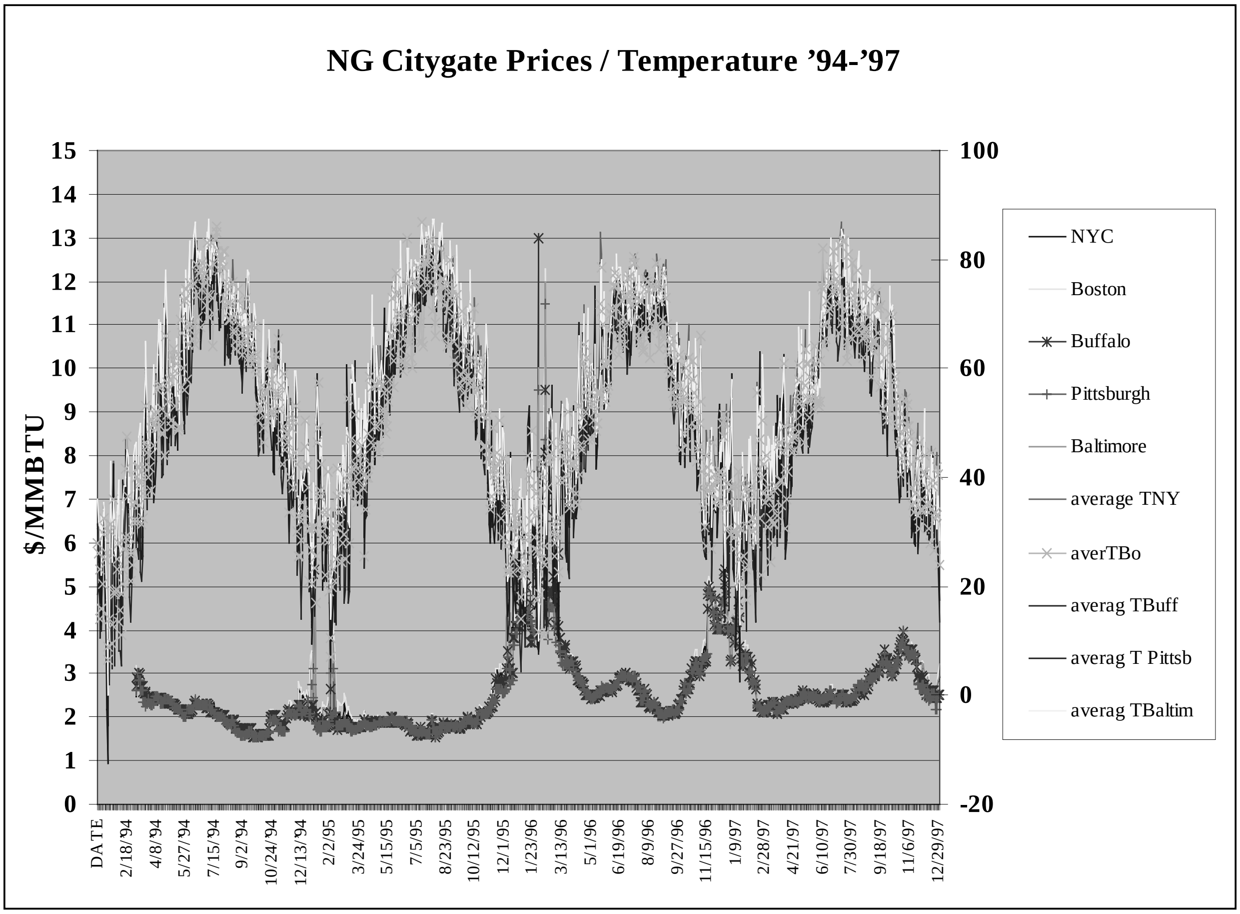
Data Source: Bloomberg Energy.

This figure also shows that, quite aside from the extreme volatility, the difference between Henry Hub and the Northeastern pricing points varies according to the season, and that the premium expands as winter approaches and diminishes greatly as summer returns. We turn now to the consideration of the influence of weather on the observed pricing patterns.

4.3. Weather

The general pattern of average daily temperature and Northeastern citygate prices is given in **Figure 10**. As would be expected, colder temperatures correspond to the periods of highest and most variable prices for natural gas.

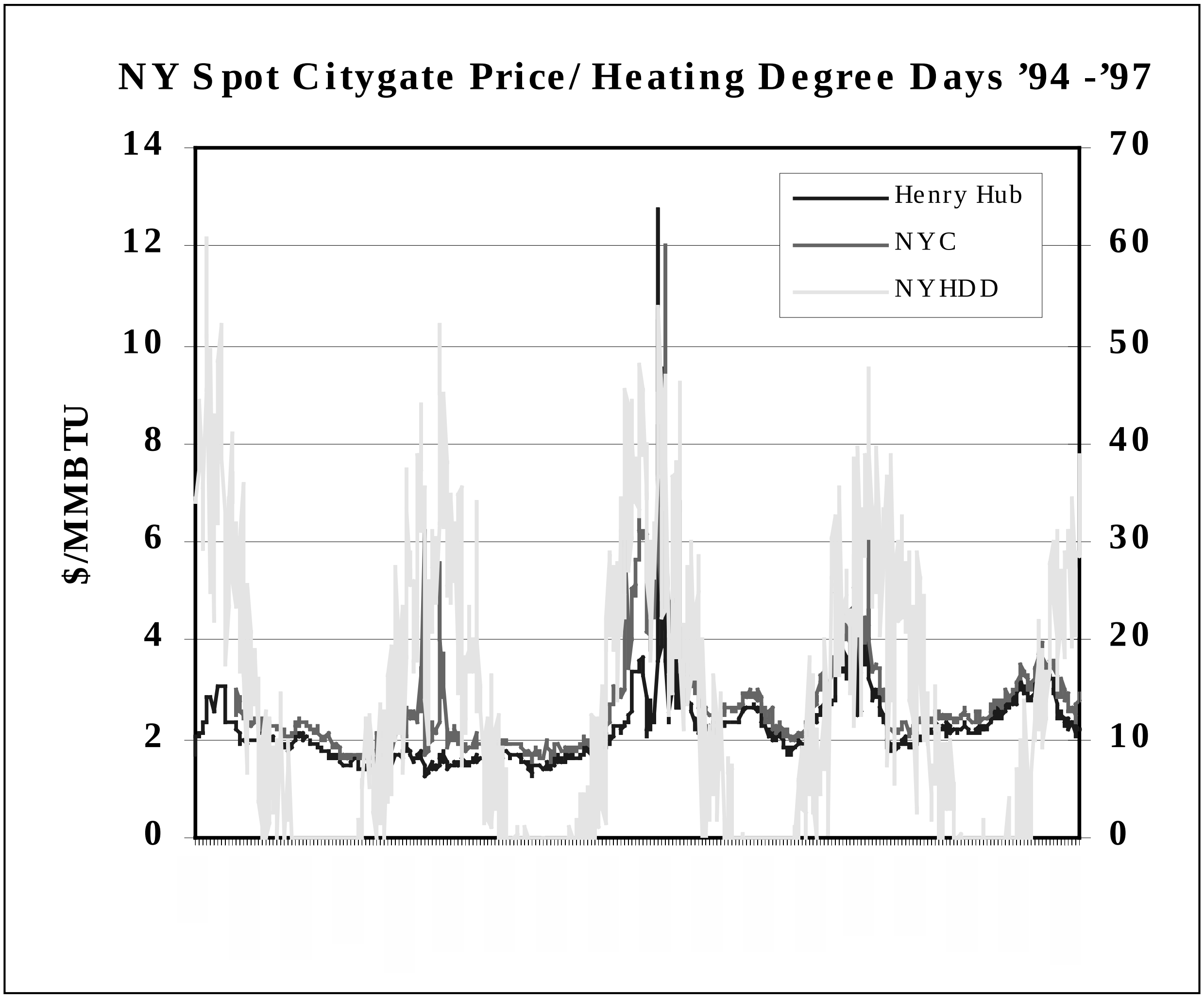
Figure 10. Natural Gas Citygate Price / Temperature (from degrees Fahrenheit)*.



**Conversion, Fahrenheit into Celsius:* 5/9(°F – 32)

Interestingly, natural gas prices are affected by cold but not warm weather., While natural gas is heavily used for heating during the winter, there is relatively little demand during the summer, because the principal seasonal demand for energy, air-conditioning, is met by electricity, and there is relatively little demand for natural gas to supply fuel mixes for power generation. Natural gas citygate prices in the Northeast are therefore greatly affected by cold weather, but hardly impacted by warm weather. Accordingly, the appropriate unit of measure is the *heating degree-days*. In **Figure 11,** heating degree-days and natural gas prices are displayed graphically for New York.

Figure 11. NYC Spot Citygate Price / Heating Degree-days.



The effect of the heating degree-days varies considerably from year-to-year, but the over-all positive correlation between natural gas spot price and heating-degree days is evident.

Table 3 provides a complete correlation matrix for prices and heating degree-days at the five Northeastern locations plus the price at Henry Hub. The previously noted strong correlations among the Northeastern natural gas pricing locations is shown in the top triangle that is bold-faced. It is also evident from the lower triangle, also bold-faced, that the correlation in heating degree-days is, not surprisingly, very strong. Also, the direct correlation between price and heating degree-days at each location, denoted by the diagonal highlight, is important, but not of the same order of magnitude as with the price at Henry Hub. Finally, the correlation between

Northeastern heating degree-days and the price at Henry Hub is noticeable, but the weakest of all the correlations in this matrix.

Table 3. Correlation Factors between Natural Gas Prices and Heating Degree-days at the Henry Hub and northeastern natural gas citygate prices.

	HH	NYC	Bo	Buff	Pitt	Balt	NYhdd	Bohdd	Bufhdd	Pithdd	Balhdd
HH	1.00										
NYC	**0.83**	1.00									
Boston	**0.83**	**0.99**	1.00								
Buffalo	**0.90**	**0.95**	**0.95**	1.00							
Pitt	**0.87**	**0.97**	**0.96**	**0.98**	1.00						
Baltimore	**0.86**	**0.97**	**0.97**	**0.96**	**0.98**	1.00					
NYChdd	*0.35*	*0.57*	*0.58*	*0.48*	*0.48*	*0.52*	1.00				
Bohdd	*0.30*	*0.52*	*0.53*	*0.44*	*0.44*	*0.49*	***0.97***	1.00			
Buffhdd	*0.34*	*0.55*	*0.56*	*0.47*	*0.47*	*0.51*	***0.95***	***0.93***	1.00		
Pitthdd	*0.36*	*0.56*	*0.57*	*0.47*	*0.47*	*0.52*	***0.94***	***0.90***	***0.96***	1.00	
Balthdd	*0.38*	*0.58*	*0.58*	*0.49*	*0.49*	*0.54*	***0.97***	***0.93***	***0.93***	***0.95***	1.00

Bold numerals: Correlation between Natural Gas Prices at Henry Hub and selected other Citygates
Italic numerals: Correlation between Heating degree-days at Henry Hub and other Citygates
Bold Italic numerals: Correlation between Heating degree-days at Citygates other than Henry Hub
HH= Henry Hub; Bo=Boston; Buff=Buffalo; NYC= New York City; Pitt=Pittsburgh; Balt=Baltimore;
hdd= Heating degree-days by city.

We now use the same regression technique and equation as in Section 4.2.1 but add an additional regressor, heating degree-days. In the case of New York, given at **Table 4.1**, the additional term improves the fit considerably and both heating degree-days and the price at Henry Hub are significantly different from zero, as is the constant.

Table 4.1. Regression of New York Citygate price, using two independent variables.

Number of observations = 965 (for all regressions)

Adj R-squared = 0.7840

New York Citygate	Coefficient	Std. Error	*t*-statistic*
Henry Hub	1.008346	.0223712	45.073 (0.4)
NY Heating-Degree Days	.0271223	.0013637	19.888
Constant	.1429026	.0488041	2.928

* T-statistic is parentheses is the test of β=1.0.

In fact, the coefficient on the price at Henry Hub is insignificantly different from one; and the difference between New York and Henry Hub appears as a constant $0.143/mmBtu plus a variable charge that reflects heating demand. The suggested pricing relationship is given below.

P_{NYC}= *14.29 cents/MMBTU+ 2.7 cents/MMBTU (for each change of 10 HDD)+ 1.0083**P_{HH}

Tables 4.2–4.5, which show regression results for this study's final four citygate prices, can be explained in the same way as has been done for New York.

Table 4.2. Regression of Boston Citygate price, using two independent variables.

Adjusted R-squared = 0.7786

Boston Citygate	Coefficient	Std. Error	*t*- statistic*
Henry Hub	1.0465	0.023188	45.13 (2.0)
NY Heating-Degree Days	0.0294	0.001413	20.82
Constant	0.1187	0.050588	2.346

* T-statistic is parentheses is the test of β=1.0.

Table 4.3. Regression of Buffalo Citygate price, using two independent variables.

Adjusted R-squared = 0.8329

Buffalo Citygate	Coefficient	Std. Error	t- statistic*
Henry Hub	1.0199	0.01730	58.967 (1.2)
NY Heating-Degree Days	0.0116	0.00085	13.675
Constant	0.1488	0.03804	3.912

* T-statistic is parentheses is the test of β=1.0.

Table 4.4. Regression of Pittsburgh Citygate price, using two independent variables.

Adjusted R-squared = 0.7851

Pittsburgh Citygate	Coefficient	Std. Error	t- statistic*
Henry Hub	0.9687	0.01939	49.943 (1.6)
NY Heating-Degree Days	0.0117	0.00102	11.465
Constant	0.2674	0.04225	6.330

* T-statistic is parentheses is the test of β=1.0.

Table 4.5. Regression of Baltimore Citygate price, using two independent variables.

Adjusted R-squared = 0.7898

Baltimore Citygate	Coefficient	Std. Error	t- statistic*
Henry Hub	0.9516	0.02010	47.321 (2.4)
NY Heating-Degree Days	0.0200	0.00125	16.070
Constant	0.2768	0.04349	6.365

* T-statistic is parentheses is the test of β=1.0.

The basic pattern observed in New York obtains with some variation at the other pricing points. The effect of heating degree-days is clearly observable: the coefficient is always positive an significant, and it has the effect of systematically reducing the coefficient on the price at Henry Hub to values that are within the 95% confidence interval of unit for four locations and very little out of it for the fifth, Baltimore. There are also interesting differences and similarities. Boston and New York, the locations farthest from sources of supply and competing markets, are very similar. The effect of heating degree-days is noticeably greater at these two locations than at any of the other three; and this effect is not just a reflection of temperature. Buffalo is famously colder than either New York or Boston. Pittsburgh and Baltimore also show similarity. The constant and coefficient on Henry Hub price are indistinguishable statistically, but heating degree-days has a greater effect at Baltimore, although still less than in New York or Boston. Buffalo is a hybrid: constant and coefficient on Henry Hub similar to what is observed in Boston and New York, but with much less effect from heating degree-days.

4.4.Natural Gas Storage

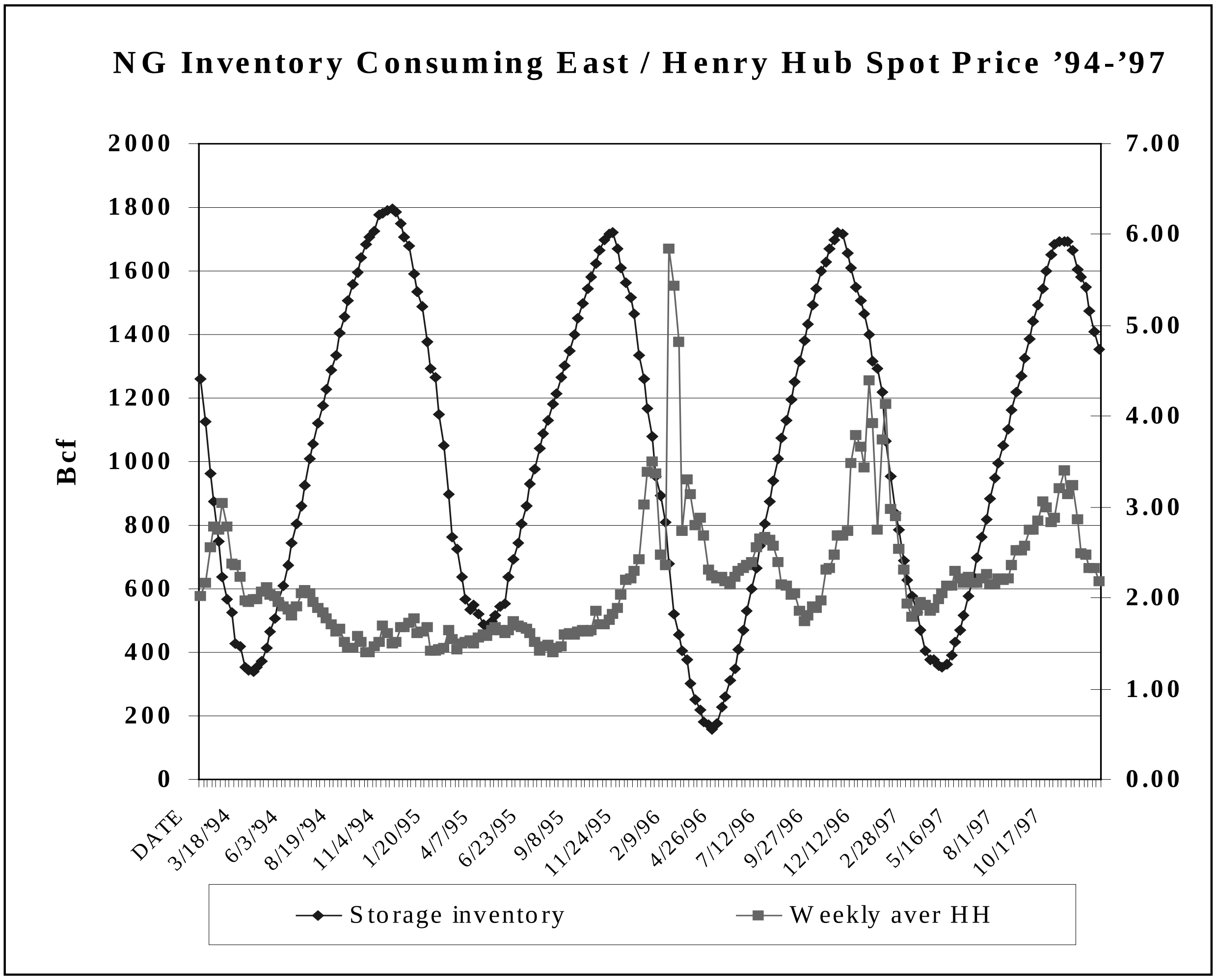
Storage is often cited as an important consideration in explaining natural gas prices. There is an immediate problem with the data. Natural gas storage inventory is only reported on a weekly basis, whereas all the the data considered so far has been on a daily basis (excluding week-ends when pricing data is not available). Accordingly, it has been necessary to calculate weekly averages from the natural gas pricing and heating degree-day series, which necessarily suppresses much of the daily volatility. Nevertheless, changes in inventory will reflect, among other things, the cumulative effect of temperature during the week; and it is reasonable to assume that daily pricing takes into account both weekly reported storage levels and the implications of currently observed temperature on future storage levels. There is also a necessary loss of observations, but the number is still sufficient (199 vs. 967) for good statistical accuracy if there is a relation.

Table 5 and **Figure 12** provide the summary picture and statistics on the weekly observations between storage and Northeastern citygate prices. The pattern of storage is very regular, but there is surprisingly little correlation between storage levels in the Consuming East and the citygate prices at any of these Northeastern pricing points.

Table 5. Correlation between Natural Gas Spot Price and Inventory in the Consuming East.

	Henry Hub	***NY Citygate***	***Boston Citygate***	***Buffalo Citygate***	***Pittsburgh Citygate***	***Baltimore Citygate***
Inventory Level, Consuming East	- .0337	- 0.062	- .0704	- 0.0974	- 0.1022	- 0.0821

Figure 12. Natural Gas Storage Inventory Level (Bcf)/ Henry Hub Spot Price ($/MMBtu)



Tables 6.1-6.5 provide the regression results for the same regression equation but with weekly data and with the addition of the inventory level.

Table 6.1. Regression of New York Citygate price, using three independent variables.

Number of Observations = 199 (for all regressions)

Adj R-squared = 0.8462

New York Citygate	Coefficient	Std. Error	*t*-statistic*
Henry Hub	1.1393	0.0455	25.69 (3.1)
Heating-Degree Days	0.0322	0.0020	8.63
Storage inventory	-0.000017	0.0000621	-0.27
Constant	-0.27458	0.1191	-2.31

* T-statistic is parentheses is the test of β=1.0.

Table 6.2. Regression of Boston Citygate price, using three independent variables.

Adj R-squared = 0.8522

Boston Citygate	Coefficient	Std. Error	*t*-statistic*
Henry Hub	1.2079	0.04569	26.438 (4.5)
Heating-Degree Days	0.0249	0.00249	10.005
Storage inventory	-0.000007	0.00006	-0.119
Constant	-0.2236	0.1205	-1.856

* T-statistic is parentheses is the test of β=1.0.

Table 6.3. Regression of Buffalo Citygate price, using three independent variables.

Adj R-squared = 0.8900

Buffalo Citygate	Coefficient	Std. Error	*t*-statistic*
Henry Hub	1.1259	0.03354	33.56 (3.8)
Heating-Degree Days	0.0100	0.0016	6.35
Storage inventory	-0.00008	0.00005	-1.910
Constant	0.040	0.08694	0.467

* T-statistic is parentheses is the test of β=1.0.

Table 6.4. Regression of Pittsburgh Citygate price, using three independent variables.

Adj R-squared = 0.8765

Pittsburgh Citygate	Coefficient	Std. Error	*t*-statistic*
Henry Hub	1.1086	0.0356	31.125 (3.1)
Heating-Degree Days	0.00953	0.0018	5.264
Storage inventory	-0.00012	0.00005	-2.585
Constant	0.12393	0.09093	1.363

* T-statistic is parentheses is the test of β=1.0.

Table 6.5. Regression of Baltimore Citygate price, using three independent variables.

Adj R-squared = 0.8763

Baltimore Citygate	Coefficient	Std. Error	*t*-statistic*
Henry Hub	1.0785	0.03722	28.971 (2.1)
Heating-Degree Days	0.0178	0.0022158	8.033
Storage inventory	- 0.000085	0.000049	-1.747
Constant	0.1161	0.09422	1.232

* T-statistic is parentheses is the test of β=1.0.

The weekly data provide a higher R-squared than the daily data, and they confirm that the price at Henry Hub and heating degree-days are important explanatory variables in the pricing of natural gas in the Northeast. The coefficients for heating degree-days are almost identical to those obtained with the daily data. The relationship between the constant term and the coefficient on the price at Henry Hub is different, however. Whereas the daily data indicated a significant constant term and a Henry Hub coefficient close to unity, the weekly data provide an imprecisely estimated constant and a coefficient on Henry Hub that is always greater than one. Instead of a transportation charge that is constant, these data suggest that the transportation charge is proportional to the price at Henry Hub. Finally, the level of storage in the Consuming East is only weakly discernable at Buffalo, Pittsburgh and Baltimore, and not at all so in New York and Boston.

5. Conclusion

The Northeastern United States is a natural gas importing region, amply equipped with pipelines and natural gas storage facilities, that is supplied from both the Gulf of Mexico and Canada. The very high degree of correlation (> +0.95) between natural gas prices from 1994 through 1997 at five cities that constitute the core and periphery of this region—New York, Boston, Buffalo, Pittsburgh and Baltimore—define the Northeast as a single natural gas market.

Two factors—the natural gas price at the Henry Hub, a major pricing point for supplies from the Gulf of Mexico, and local heating degree-days—explain more than three-quarters of the variation in citygate prices at these five locations. This conclusion emerges from analysis using ordinary least squares regression of both a daily price series over the four years, consisting of nearly a thousand observations, or from weekly averages of those daily observations. The results of the daily and weekly series differ with respect to the exact relation of Northeastern citygate prices to Henry Hub. The daily series suggests a constant term, varying with location, that is additive to the price at Henry Hub, whereas the weekly series suggests a relationship that is proportional to the price at Henry Hub. The regressions on the two data series agree however on the effect of heating degree-days. Similar values are yielded by at every location, and both data series indicate that heating degree-days have considerably more effect on citygate prices at the interior points, Boston and New York, than on the peripheral locations of Buffalo, Pittsburgh and Baltimore.

A surprising result of this analysis is that the current inventory levels at natural gas storage facilities in the region have little influence on citygate prices. At best, there is a weakly discernible effect at the peripheral locations. Data and time constraints did not permit a more exhaustive exploration of this issue. Storage levels are highly seasonal and thus, with some lead, highly correlated to heating degree-days. The effect of inventory may be not so much the current level, as the current level relative to some norm.