NATURAL GAS PRICES AND THE GAS STORAGE REPORT: PUBLIC NEWS AND VOLATILITY IN ENERGY FUTURES MARKETS

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This study examines the short-term volatility of natural gas prices through an examination of the intraday prices of the nearby natural gas futures contract traded on the New York Mercantile Exchange. The influence on volatility of what many regard as a key element of the information set influencing the natural gas market is investigated. Specifically, we examine the impact on natural gas futures price volatility of the Weekly American Gas Storage Survey report compiled and issued by the American Gas Association during the period January 1, 1999 through May 3, 2002 and

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the subsequent weekly report compiled and issued by the U.S. Energy Information Administration after May 6, 2002. We find that the weekly gas storage report announcement was responsible for considerable volatility at the time of its release and that volatility up to 30 minutes following the announcement was also higher than normal. Aside from these results, we document pronounced price volatility in this market both at the beginning of the day and at the end of the day and offer explanations for such behavior. Our results are robust to the manner in which the mean percentage change in the futures price is estimated and to correlation of these changes both within the day and across days. Jrl Fut Mark 24:283–313, 2004

INTRODUCTION

Information on the quantity of a commodity in storage and how this quantity changes over time should be integral to the behavior of the commodity's price. This study examines the short-term volatility of natural gas futures prices by studying the behavior of intraday prices for the nearby natural gas futures contract traded on the New York Mercantile Exchange (NYMEX) and how price volatility is influenced by new information about the amount of gas in storage. Understanding natural gas price volatility and its determinants is not simply a matter of academic interest, however. It is of practical importance as well given the level of trading activity in the spot and futures markets for this commodity.[1]

This study focuses on how natural gas price volatility behaves around the time the weekly report on natural gas under storage in the United States is released. The study spans the period January 1, 1999 through October 31, 2002. The weekly gas storage report (henceforth the Storage Report) was compiled and released by the American Gas Association (AGA) up until the end of April 2002, after which the U.S. Energy Information Administration (EIA) has prepared the report.[2] The theory of storage as recently elaborated by Deaton and Laroque (1992, 1996) and Chambers and Bailey (1996) suggests that changes in information about the amount of a commodity under storage can create variability in the price of that commodity.[3] Information about changes in the

[1]An understanding of natural gas price volatility also has important implications for the valuation of options on natural gas futures.

[2]The Appendixes contain examples of the AGA Weekly Gas Storage Report and the Weekly Natural Gas in Storage Report issued by the EIA. A detailed review of the methods used by the AGA in preparing the storage estimates is available at <http://www.aga.org/pdf/StatsStudies/methodology 2001update.pdf>. The methods used by the EIA are detailed at <http://tonto.eia.doe.gov/oog/info/ngs/methodology.html>.

[3]The Theory of Storage has a long history. Many important contributions have been made to this literature including the familiar works of Kaldor (1939), Working (1949), Brennan (1958), Telser (1958), Samuelson (1971), Newbery and Stiglitz (1981), and especially the book by Williams and Wright (1991).

amount of natural gas in storage may result in mean price shifts or variability around the mean, especially if participants in the market do not interpret the information in the same fashion, that is, when interpretations are heterogeneous.

Anecdotal evidence on the effects of gas storage information announcements has circulated for years and appears frequently in industry publications such as the *Gas Daily*. Further, industry regulators as well as traders have raised repeated concerns about the gas storage reports. One concern is the reliance on a single source for the storage information.[4] A second concern not unrelated to the first is that the storage numbers are taken very seriously by traders, and that trader perceptions of the implications of the storage numbers are a crucial element in determining how prices respond (*Platts Gas Daily,* October 12, 2001). Numerous observers, including market traders as well as the chairman of the Federal Energy Regulatory Commission, Pat Wood, have suggested the market has over-relied on the weekly report, and indeed that the strong reliance on a single piece of data is not a healthy situation. Wood, in a comment about the market reaction to an apparent error in the report issued on August 15, 2001, was quoted as saying "One little hiccup and everyone went crazy" (as reported in *Gas Daily,* October 12, 2001). Despite these concerns, to our knowledge, there has been no systematic study of the relation between intraday natural gas price volatility and the weekly gas storage announcement. Our study however has implications beyond the natural gas market. Specifically, our results have implications for understanding the effects of public news on the volatility of commodity futures prices in general and especially prices in energy markets.

The Storage Report is interesting for several reasons. First, market participants have generally regarded the announcement as one of the most important pieces of news influencing the natural gas market. Second, similar to macroeconomic announcements, the Storage Report may not necessarily be interpreted identically by all market observers.[5] Third, prior to March 2, 2000, the press release on the state of gas in storage was distributed following the close of the NYMEX on Wednesday. However, up until the end of April 2002 the report was consistently released during the interval 2:00–2:15 PM on Wednesdays during the

[4]As reported in *Platts Gas Daily*, October 12, 2001, McGraw-Hill Companies, Inc.

[5]See Ederington and Lee (1993). The influence of macroeconomic information announcements on volatility has been examined in several settings, but not to our knowledge in the natural gas market. Examples of recent studies include Ederington and Lee (1993, 1995), McQueen and Roley (1993), Harvey and Huang (1991, 1992), Hardouvelis (1988), and Cornell (1983). Webb (1994) provides a comprehensive survey of the influence of macroeconomic information announcements on securities markets.

NYMEX trading day. Since the EIA took over the reporting function at the beginning of May 2002 (the EIA issued the first report on May 9, 2002 for gas in storage as of Friday, May 3, 2002), the report has been released around 10:30 AM on Thursday. Our data set provides a nice clean experiment for examining the impact of the storage announcement on prices since there are three periods within which a different announcement regime was in use. Further, because our data set extends through October 2002, it provides us with the opportunity to assess how the volatility of natural gas prices behaves under the reporting regime that is expected to continue into the indefinite future.

Academic studies of natural gas price volatility are limited, and in particular we could identify no studies of intraday volatility. In addition, those studies that have examined volatility have tended to focus less on understanding the determinants of volatility and more on asking whether extant statistical models of variability fit the data. One such study (Duffie & Gray, 1995) has modeled natural gas price variability using models that assume time-varying volatility.[6] Duffie and Gray find that conventional, time-varying volatility models do not adequately fit the data or provide good forecasts of natural gas price volatility.

Trading activity by gas marketers is significant.[7] Daily trading in natural gas futures contracts is on the order of 30,000–50,000 contracts for the front month and 10,000–30,000 for the next contract in line. The trading unit for a single contract traded on the New York Mercantile Exchange is stated as 10,000 million Btu's. As such, if 40,000 contracts were traded on any day this would amount to 400 trillion Btu's. On Wednesday, October 23, 2002, 44,281 front-month contracts were traded amounting to a notional value of roughly $1.88 billion, while the December contract volume was 13,976 or roughly $0.61 billion.

Natural gas is priced at various delivery points throughout the nation. The daily spot market for gas is largely decentralized although in recent years numerous on-line trading systems have emerged, such as the Intercontinental Exchange (ICE) and the ongoing system maintained by Williams.[8] Price discovery for trades of short duration is relatively easy in the spot market. Price discovery for longer duration trades is more difficult.

[6]Specifically Duffie and Gray fit models from the family of autoregressive conditional heteroscedasticity processes—ARCH models (Bollerslev, 1986; Engle, 1982; Nelson, 1991).

[7]The top 23 North American marketers conducted trades totaling 175.4 (Bcf/day) during the third quarter of 2002, as compared with 138.7 (Bcf/day) during the third quarter of 2001 (Source: *Platts Gas Daily*, Vol. 19, No. 234, December 6, 2002).

[8]Information on the Williams system can be viewed at <http://www.tradespark.com/home.php>.

While the daily spot and nearby futures contract prices are highly correlated (on the order of 99%), there are important differences about trading in the spot market and trading in the futures market. For instance, on a daily basis, spot trading typically concludes by 10:00 AM. In contrast, the NG futures contract is currently traded on the NYMEX from 10:00 AM through 2:30 PM. The NYMEX contract is a standardized contract.[9] Trading in this contract began in April 1990.[10] In addition, the futures contract trades overnight via the electronic system ACCESS, although liquidity is quite low.

The paper begins with a brief description of the Storage Report that was issued by the American Gas Association Weekly Gas Survey and the current report being compiled and issued by the Energy Information Administration. The basic results are then presented and discussed. Results based upon controls for conditional mean effects and correlation of returns within the day as well as across days are then presented. The final section presents a summary and our conclusions.

SUPPLY AND DEMAND INFORMATION AND THE WEEKLY AMERICAN GAS STORAGE SURVEY

Natural gas futures prices are influenced by factors affecting supply and demand. Factors that influence supply conditions are stock levels of gas in storage, pipeline capacity, operational difficulties, and imperfect information on the part of suppliers. Factors affecting demand generally include weather conditions and aggregate economic/business conditions.

The theory of price determination for a storable commodity (see Deaton & Laroque (1992, 1996) and Chambers & Bailey (1996)) suggests the price of natural gas should increase as supplies decline and/or demand increases. Therefore, unexpected changes in the level of storage should reveal new information about supply and demand conditions and may create shifts in uncertainty especially if all market participants do not interpret the information in the same manner.

[9]A cubic foot of natural gas on average gives off 1,000 Btus. One Btu (British Thermal Unit) is the amount of heat required to raise the temperature of one pound of water from 60 to 61 degrees Fahrenheit at normal atmospheric pressure (14.7 pounds per square inch). See <http://www.nymex.com> for a description of the natural gas futures contract.

[10]The Kansas City Board of Trade introduced and began trading a U.S. Western natural gas contract in August of 1995. The delivery point for this contract is the Waha Hub in West Texas. The demand for the contract however had evaporated by February of 2000. The KCBT still "lists" the contract as available, but there has been no volume since that date.

The position of the AGA regarding the storage report was summarized succinctly in the following statement. "The American Gas Storage Survey (AGSS) is designed to provide a weekly estimate of the change in inventory level for working gas in storage facilities across the United States, using a representative sample of domestic underground storage operators." (Issue Brief 2001–03, Policy Analysis Group, American Gas Association). Between 2:00 and 2:15 PM each Wednesday between February 26, 2000 and May 1, 2002, the American Gas Association released the results of the AGSS. The numbers released on any Wednesday were for gas in storage as of 9:00 AM Friday of the prior week.[11] The weekly report presented statistics on the change in gas in storage from the prior week, gas in storage for the same week one year prior, the average gas in storage for the prior five years, the estimated capacity of the storage units, and the percentage of total storage capacity currently being used. As already pointed out, the Energy Information Administration took over the reporting function at the beginning of May 2002. The statistics reported by the EIA are similar in nature to those that had been reported by the AGA.[12] One key difference however is the time and day when the EIA report is released. The EIA has selected to release the report at around 10:30 AM Eastern Time on Thursday. Illustrative examples of the AGA report and the EIA report are presented in the Appendixes.

VOLATILITY OF NATURAL GAS PRICES

Intraday Volatility

Volatility of the log price ratios is examined for the nearby natural gas futures contract traded on the New York Mercantile Exchange. Henceforth for convenience we refer to the log price ratios as "returns" and adopt the notation $r_{i,t} = \ln(P_{i,t}/P_{i-1,t})$ for the "return" on any particular day t, where i is an index that identifies the time interval over which the percentage change in price is measured. For instance, 2:00–2:05 PM is one time interval examined. The raw data are tick-by-tick price data for the nearby natural gas contract traded on the NYMEX.[13] We focus on the five-minute intervals defined over a trading day. The sample period examined extends

[11]The procedures and methods used in gathering and processing the data are described in Issue Brief 2001–03 of the AGA available at <http://www.aga.org/pdf/StatsStudies/methodology2001update.pdf>.

[12]The methods used by the EIA for gathering and preparing the weekly report can be found at <http://tonto.eia.doe.gov/oog/info/ngs/methodology.html>.

[13]The raw data were obtained from Tick Data, Inc., Great Falls, VA.

from January 1, 1999 through October 31, 2002. The September 11, 2001 tragedy disrupted futures markets everywhere, but in particular the NYMEX. We selected to exclude the period September 11, 2001 through October 7, 2001 from the study based upon the fact that this calendar time period deviated significantly from what might be regarded as normal for this market. The return standard deviation of each five-minute interval is computed across days.

An Initial Look at Volatility

The NYMEX Natural Gas futures contract began trading each day at 10:00 AM Eastern Time up until September 8, 2000 at which time the opening shifted to 9:30 AM.[14] Immediately following September 11, 2001, the opening and closing times varied until October 8, 2001, at which time they were fixed at 10:00 AM and 2:30 PM. Further, the AGA gas storage estimates were released after the close of the NYMEX trading in natural gas futures on Wednesdays during the period January 1, 1999 through February 25, 2000, while during the period February 28, 2000 through May 3, 2002, the estimates were released between 2:00 and 2:15 PM on Wednesdays. Nearly all of the reports in the sample that were released during the day on Wednesday were released at 2:00 PM. Since May 6, 2002, the report has been released by the EIA between 10:30 and 10:40 AM on Thursday. We partition the sample into five subperiods: January 1, 1999 through February 25, 2000 (report issued after the close of NYMEX trading on Wednesday by AGA, open and close of NYMEX trading: open 10:00 AM, close 3:10 PM); February 28, 2000 through September 7, 2000 (report issued around 2:00 PM on Wednesday by AGA, open 10:00 AM, close 3:10 PM); September 8, 2000 though September 10, 2001 (report issued around 2:00 PM on Wednesday by AGA, open 9:30 AM, close 3:10 PM); October 8, 2001 through May 3, 2002 (report issued around 2:00 PM on Wednesday by AGA, open 10:00 AM, close 2:30 PM); May 6, 2002 through October 31, 2002 (report issued around 10:30 AM on Thursday by EIA, open 10:00 AM, close 2:30 PM).

Figure 1 presents the volatilities during the period that the AGA storage estimates were released after the close on Wednesdays along with the volatilities for the time periods during which the AGA report was released during the day on Wednesdays and the volatilities for the calendar period during which the EIA has released the report during Thursday. Panel A presents the first three subperiods while Panel B presents the last

[14] All clock times mentioned throughout the paper are Eastern Time, unless otherwise noted.

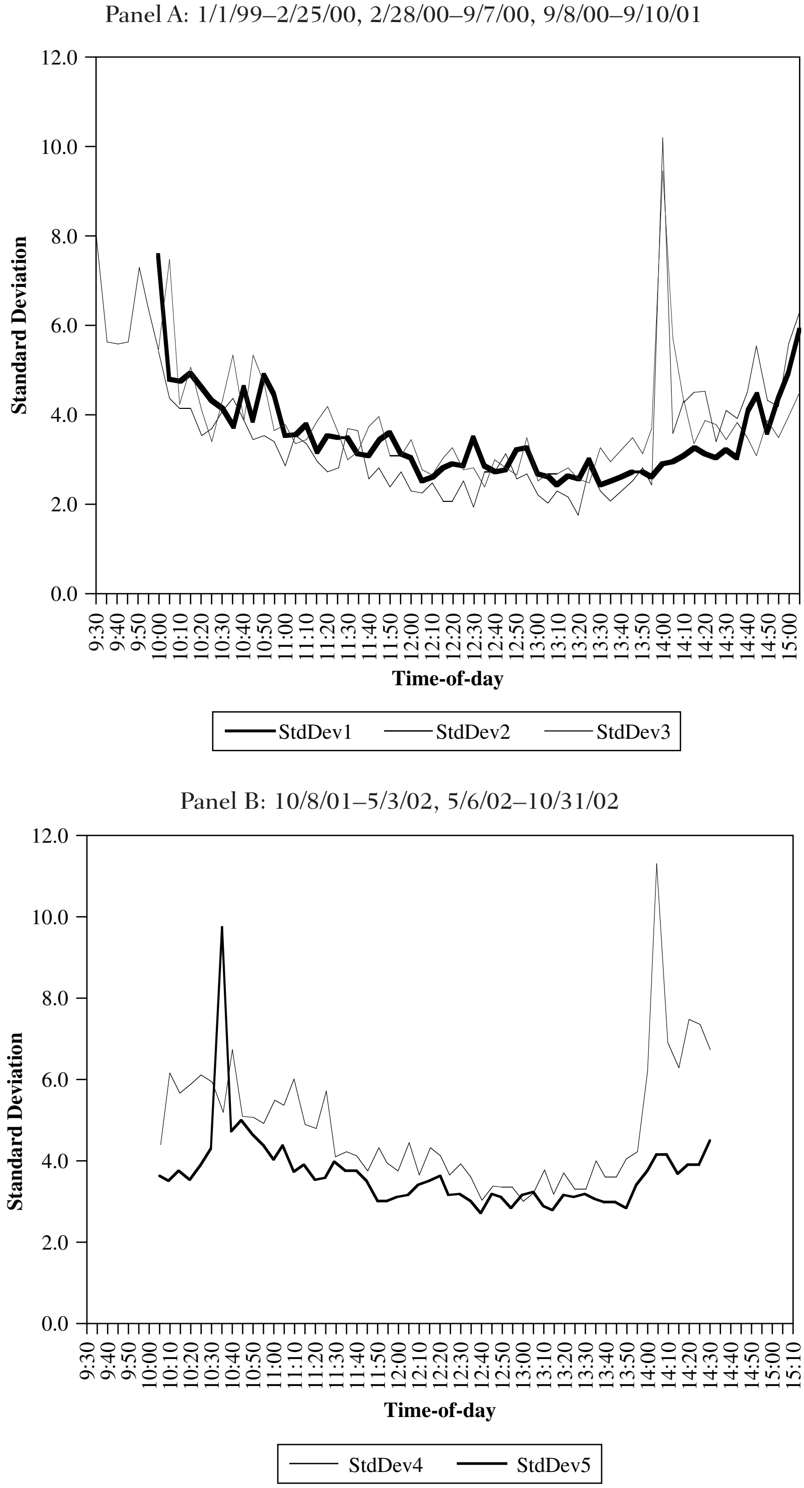


FIGURE 1
Intraday return volatilities.

Return standard deviations ($\times 10^3$) of the five-minute intervals within the day beginning for the nearby natural gas futures contract traded on the NYMEX. Standard deviations are computed across days for each of five calendar periods: 1/1/99–2/25/2000 (StdDev1), 2/28/2000–9/7/2000 (StdDev2), 9/8/2000–9/10/2001 (StdDev3), 10/8/2001–5/3/2002 (StdDev4), 5/6/2002–10/31/2002 (StdDev5).

two. A comparison of the plots in Panel A reveals the dramatic influence of the storage report. During the period when the AGA report was released after hours, the 2:00–2:05 PM volatility is of the same order of magnitude as the volatilities of the surrounding intervals. In contrast when the report was issued during the day, volatility of the 2:00–2:05 PM interval exceeded the volatilities of the surrounding intervals by a considerable amount. A general U-shaped pattern in the volatilities (ignoring the 2:00–2:05 PM interval) is present across all three subperiods, and does not appear to be influenced by the opening time difference or the AGA announcement. High volatilities at the beginning of the day are similar to what others have documented for a host of financial securities.[15] Inspection of Panel B reveals that abnormal volatility at the time of the announcement is independent of the organization compiling and releasing the information. The bold line in Panel B shows that volatility also spikes around the EIA announcement at 10:30 AM on Thursday. Finally, volatility tends to be largest during the last two calendar subperiods.

Table I presents formal test results of the null hypothesis that the variances across intraday time intervals are equal. The test statistic employed is the Brown-Forsythe modified Levine test statistic.[16] Panel A of Table I presents the test statistics associated with the null hypothesis that variance is equal across each of the five-minute intervals within the day, pooling all days within the calendar interval. Results are presented for each of the five calendar subperiods, and for the last four subperiods, tests are also presented for Wednesdays (or Thursdays in the case of the last subperiod) only and for all other days excluding Wednesdays (or Thursdays). The null hypothesis is always rejected at the 0.01 level when all days of the week are included, consistent with the visual interpretations of Figure 1. Further, the null hypothesis is consistently rejected for Wednesdays (Thursdays, last subperiod) alone as well as for all other days excluding Wednesdays (Thursdays, last subperiod). The latter result leads to the inference that variation in volatility across the five-minute intervals of the day is not confined to days on which the gas storage report was released. Inspection of Figure 1 reveals why the null is rejected even when Wednesdays (or Thursdays) are excluded: volatility at the beginning

[15]Wood, McInish, and Ord (1985), Harris (1986), Stoll and Whaley (1990), Lockwood and Linn (1991), Chan, Chan and Karolyi (1991), Harvey and Huang (1991, 1992), Ederington and Lee (1993), and Sheikh and Ronn (1994), among others.

[16]Conover, Johnson, and Johnson (1981) compare over 50 alternative tests of the null hypothesis of equality of variance and find that the Brown-Forsythe modified Levine test is among the most powerful when the null is false and has the best controlled rejection rates when the null is true. Further the test is robust to nonnormality. The test has been employed in the analysis of stock price change volatility by Lockwood and Linn (1990) and in the analysis of T-bill futures and exchange rate futures price changes by Ederington and Lee (1993).

TABLE I

Tests of Equality of Variance of Return Variates Measured Over Alternative Intervals for the Nearby Natural Gas Futures Contract

		Calendar Time Period				
Test	*Sample*	*1/1/1999–2/25/2000*	*2/28/2000–9/7/2000*	*9/8/2000–9/10/2001*	*10/8/2001–5/3/2002*	*5/6/2002–10/31/2002*
Panel A (All daily five-minute intervals)						
F_1	All days	16.14*	8.21*	14.23*	8.63*	4.63*
	Wednesdays (Thursdays) only		13.32*	17.53*	7.44*	1.40 (7.28*)
	All days excluding Wed. (Thurs.)		6.45*	11.45*	6.67*	5.69* (3.08*)
Panel B (2:00–2:05 PM intervals)						
F_1	All days	0.17	22.71*	38.33*	26.64*	2.40
	All days excluding Wednesday	0.21	0.87	2.05	0.92	2.75
Panel C (1:30–2:30 PM intervals)						
F_3	All days	0.91	34.41*	62.03*	18.45*	2.05
	All days excluding Wednesday	1.19	4.66*	7.05*	5.67*	1.56
Panel D (10:30–10:35 AM intervals)						
F_4	All days	0.22	1.70	3.78	1.76	17.02*
	All days excluding Thursday	0.14	1.08	2.99	1.76	1.68
Panel E (10:30–11:00 AM intervals)						
F_5	All days	2.21	6.46*	3.71*	2.92*	11.54*
	All days excluding Thursday	2.06	7.32*	1.80	3.24*	0.08

Note. Brown-Forsythe-Modified Levene test statistics are presented for tests of the null hypothesis that return variances are equal across various time intervals. The null hypotheses tested are specified as F_1, standard deviations are equal across all five-minute intervals of the day, pooling across days; F_2, standard deviations of the 2:00–2:05 PM time interval are equal across days of the week; F_3, standard deviations of the 1:30–2:30 PM interval are equal across days of the week; F_4, standard deviations of the 10:30–10:35 AM interval are equal across days of the week; F_5, standard deviations of the 10:30–11:00 AM interval are equal across days of the week.

The Brown-Forsythe-Modified Levene test statistic is computed as

$$F = \frac{\sum_{j=1}^{J} n_j(\bar{D}_{\cdot j} - \bar{D}_{\cdot\cdot})^2}{\sum_{j=1}^{J}\sum_{t=1}^{n_j}(D_{tj} - \bar{D}_{\cdot j})^2} \cdot \frac{(N - J)}{(J - 1)}$$

where $D_{tj} = |r_{tj} - \hat{M}_{\cdot j}|$; r_{tj} is the log price ratio (return) for day t and time interval j; $\hat{M}_{\cdot j}$ is the sample median return for interval j over the relevant n_j days; $\bar{D}_{\cdot j} = \sum_{t=1}^{n_j}(D_{tj}/n_j)$ is the mean absolute deviation from the median $\hat{M}_{\cdot j}$ for the time interval j; and $\bar{D}_{\cdot\cdot} = \sum_{j=1}^{J}\sum_{t=1}^{n_j}(D_{tj}/N)$ is the grand mean where $N = \sum_{j=1}^{J} n_j$. The test statistic is distributed $F_{J-1,N-J}$ under the null hypothesis of equality of variances across the J time intervals. Tests are conducted for each of the five subperiods defined by 1/1/99–2/25/2000, 2/28/2000–9/7/2000, 9/8/2000–9/10/2001, 10/8/2001–5/3/2002, 5/6/2002–10/31/2002.

*significant at the 1% level.

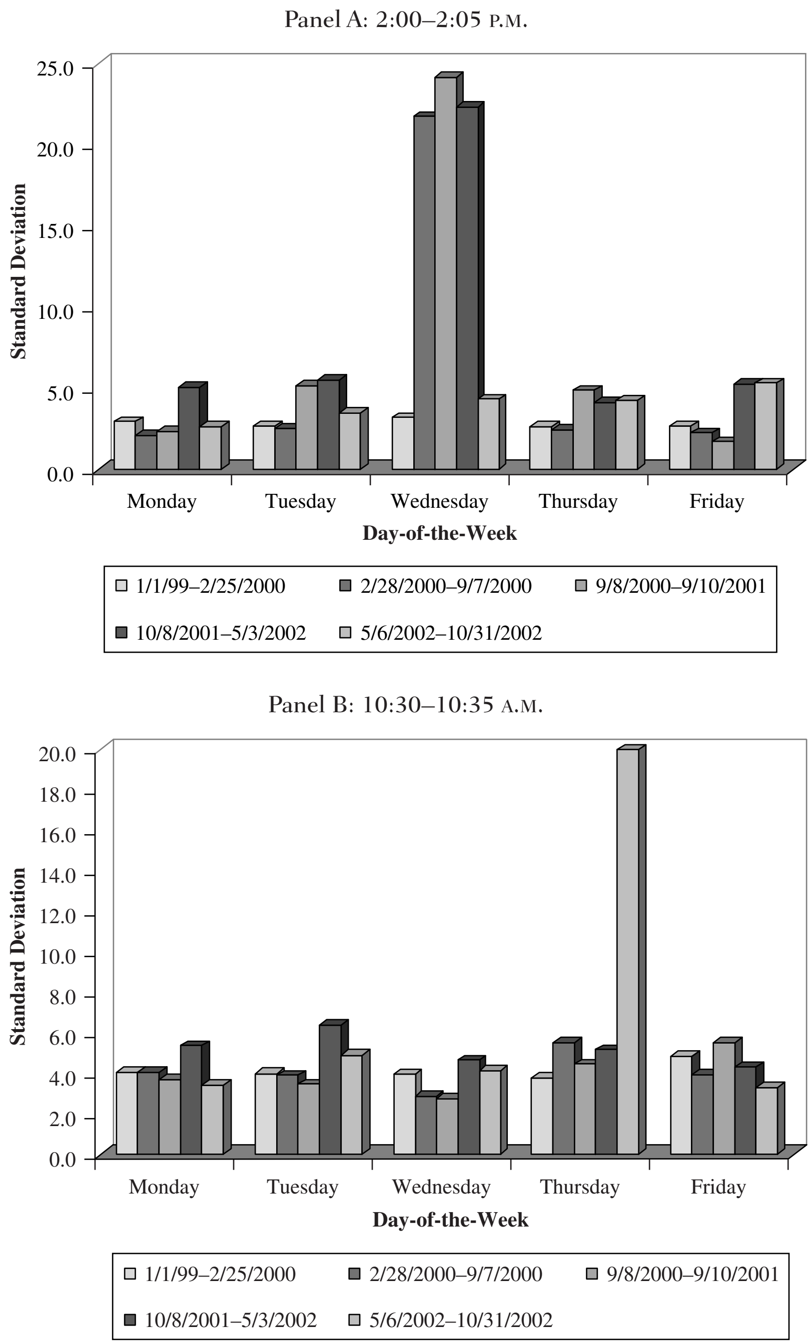


FIGURE 2

Volatility (return standard deviation $\times 10^3$) of the natural gas futures prices for the nearby contract traded on the NYMEX by day-of-the-week measured using returns for the time period 2:00–2:05 PM or 10:30–10:35 AM, for each of five calendar subperiods: 1/1/99–2/25/2000, 2/28/2000–9/7/2000, 9/8/2000–9/10/2001, 10/8/2001–5/3/2002, 5/6/2002–10/31/2002.

and ending of the day is consistently greater than volatility during the middle of the day, ignoring the 2:00–2:05 PM or 10:30–10:35 AM periods.

Weekday and Thursday Effects and the Storage Report

The volatilities of the 2:00–2:05 PM interval are graphed for each day-of-the-week by calendar subperiod in Panel A of Figure 2. The graph shows clearly that the 2:00–2:05 PM volatility on Wednesday during the middle three calendar periods is on the order of six times the 2:00–2:05 PM standard deviation during the first and last calendar period. Further, the 2:00–2:05 PM Wednesday standard deviation for the second two calendar periods is on the order of six times the standard deviations for the same time periods on the other days of the week during those periods. Panel B of Table I presents results of a formal test of the equality of the 2:00–2:05 PM standard deviations across days of the week. The null is soundly rejected for each of the middle three calendar subperiods when Wednesdays are included, but is never rejected when Wednesdays are excluded. Further, there is no significant difference between the 2:00–2:05 PM variances across days of the week during the first subperiod, the period during which the AGA report was released after the close of trading. A similar result is found for the last subperiod during which the EIA released the report at 10:30 AM.

Panel B of Figure 2 presents a different set of results, now displaying volatility by day-of-the week for only the 10:30–10:35 AM interval, the time of the EIA report release on Thursday. The figure clearly shows that volatility during this time interval is larger than normal only on Thursday during the last calendar subperiod, the period during which the EIA has been handling the report. Panel D of Table I confirms the statistical significance of the difference in the 10:30–10:35 AM volatility from the other interval volatilities during the last calendar subperiod.

Beginning and End-of-the-Day Effects

The NYMEX natural gas futures contract began trading at either 9:30 AM or 10:00 AM Eastern Time during our sample period and trading ended as late as 3:10 PM. Figure 1 shows that volatility is largest roughly during the first hour of trading (ignoring the 2:00–2:05 PM and 10:30–10:35 AM intervals). Recent studies by Ederington and Lee (1993) and Harvey and Huang (1991, 1992) posit that the early morning volatility observed in many financial markets is due to the release of macroeconomic news.

Ederington and Lee (1993) show that volatility of the nearby futures contract price in the interest rate and foreign exchange rate futures markets is concentrated on Fridays and is associated with the concentration of macroeconomic news reports released on Friday and in particular with the release of the employment report at 8:30 AM Eastern Time. If news on aggregate economic activity influences the natural gas market, then we might expect to see unusual volatility at the beginning of the day on Fridays, but less so on other days of the week. Figure 3 presents a graph of the volatility during the first 15-minute interval by day-of-the-week and by subperiod. The data suggest no unusual activity on Fridays at the immediate beginning of the day. We also conduct statistical tests for the equality of variance of the first 15-minute returns across days within each subperiod. The computed F values for the Brown-Forsythe Modified Levene test are 0.925, 2.336, 0.243, 0.639 and 2.779, for each of the subperiods, respectively. None of these statistics allow us to reject the null

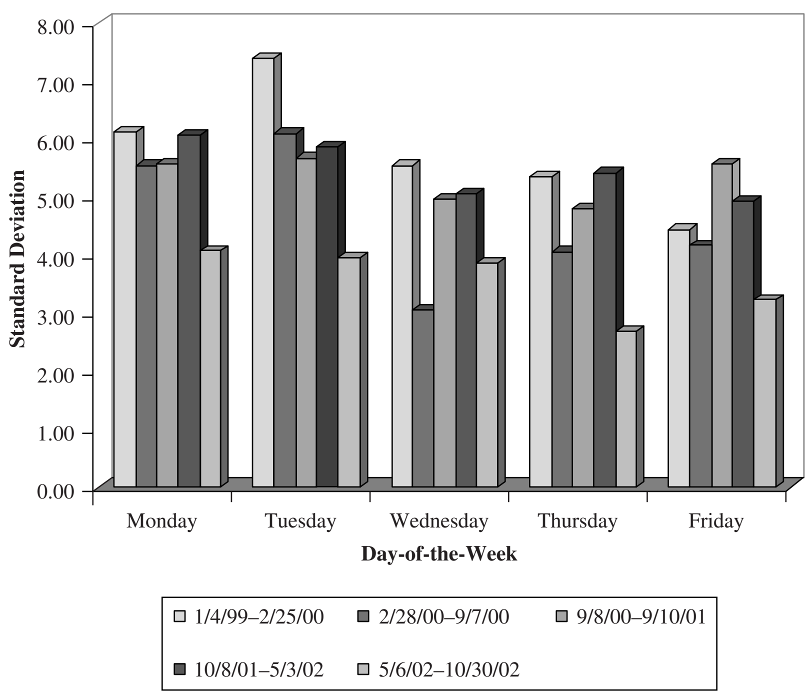


FIGURE 3

Day-of-the-week natural gas futures price volatility (return standard deviation $\times 10^3$) for the first 15 minutes of the day. Volatility of the natural gas futures prices for the nearby contract traded on the NYMEX by day-of-the-week measured using returns for the first 15 minutes of the day, for each of five calendar subperiods: 1/1/99–2/25/2000, 2/28/2000–9/7/2000, 9/8/2000–9/10/2001, 10/8/2001–5/3/2002, 5/6/2002–10/31/2002.

hypothesis that the variances are equal at the 0.05 level of significance. We conclude from these results that the macroeconomic news reports that have been shown to influence financial markets do not appear to influence the natural gas market.[17]

Several alternative hypotheses for the beginning-of-day volatility in financial markets have been presented in the literature (Admati & Pfleiderer, 1988; Amihud & Mendelson, 1983; Brock & Kleidon, 1992; French & Roll, 1986; and Hong & Wang, 2000). These authors suggest that information accumulation, heterogeneity of beliefs, private information, and market closures contribute to abnormal price volatility at the beginning of the day. For instance, information buildup on supply and demand conditions during the overnight period coupled with heterogeneity of beliefs about the implications of this information, can lead to a sorting out period during which volatility may be higher at the opening of trading. The structure of the spot market for gas may contribute to this effect's impact on natural gas prices.

The spot natural gas market is a complex network involving producers, shippers, end users, pipeline owners, and storage facility operators.[18] Transportation of natural gas via the pipelines in North America involves what is known as the *nomination* process. The *nomination* process involves a shipper filing a notification with the relevant pipeline that a certain quantity of gas will be input into the system on a given date at a given location and extracted on one or more dates at another location.[19] The process involves the identification of the party that will deliver the gas, the amount of gas and the party that will receive the gas.[20] Natural gas transactions are done on a daily basis. Typically the operating day runs on a 7:00 AM to 7:00 AM Central Time basis. Pipeline operators generally require that *nominations* for subsequent day transmissions be completed by 10:00 AM central time of the day prior to the date the gas will flow. Trading is therefore busiest in the early morning hours of any day. If, and we stress *if,* the behavior of the spot price at Henry Hub is more volatile during the early morning hours, and *if* this generates information that feeds into the NYMEX futures markets, *then* it might be possible that the structure of trading in the spot market influences volatility in the

[17]Tests using the first 30 minutes and first hour yield similar results.

[18]Excellent discussions of the market for natural gas can be found in Sturm (1997), Fitzgerald and Pokalsky (1995), and Thaler (2000) who presents an analysis of the 50 largest global gas companies and the strategies they are following.

[19]There are careful checks and balances applied by the shipper to insure the integrity of any particular nomination (see Sturm (1997), Ch. 2).

[20]Natural gas transportation is unique in that gas "flows" from high pressure areas to low pressure areas.

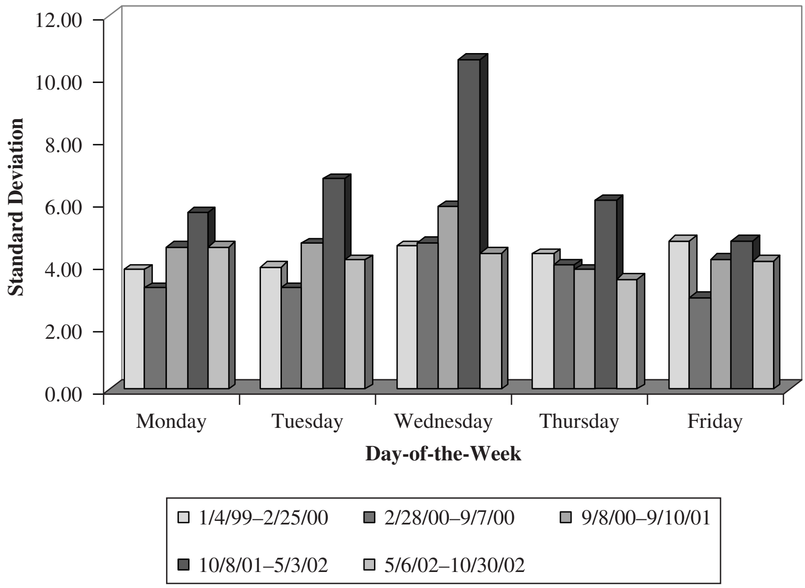


FIGURE 4
Day-of-the-week natural gas futures price volatility (return standard deviation $\times 10^3$) for the last 15 minutes of the day. Volatility of the natural gas futures prices for the nearby contract traded on the NYMEX by day-of-the-week measured using returns for the last 15 minutes of the day, for each of five calendar subperiods: 1/1/99–2/25/2000, 2/28/2000–9/7/2000, 9/8/2000–9/10/2001, 10/8/2001–5/3/2002, 5/6/2002–10/31/2002.

nearby contract price. We are unfortunately unable to formally test this proposition, as there is no ready source of intraday spot price data.

One possible explanation for the end-of-day volatility could be a disproportionate number of short-term traders in the market who close their positions near the end of the day. If this conjecture were true, we might expect to see more volatility at the end of the day on Fridays relative to other days of the week as traders close out their positions for the weekend. Figure 4 presents volatility estimates by day-of-the-week and subperiod for the last 15 minutes of the day. Volatility at the end of the day on Fridays is greater than other days only for the first subperiod, it is smaller for the remaining subperiods. A larger than normal end-of-day volatility on Wednesday appears for the fourth calendar subperiod, but this is atypical.

VOLATILITY ADJUSTMENTS

We now turn our attention to the influence of the storage report on time intervals surrounding the announcement time. Specifically, we are interested in assessing whether volatility increases before the announcement and likewise whether unusual volatility persists following the news release.

Schwert (1989) and Schwert and Sequin (1990) point out that if the log price ratio (return) is normally distributed with a constant mean but time-varying variance, the expected absolute deviation from the mean is proportional to the standard deviation, that is $E|r_{it} - \bar{r}_i| = (2/\pi)^{.5}\sigma_{it}$ where σ_{it} is the standard deviation of the return for interval i on day t. Consider the following regression formulation for time interval i:

$$|r_{it} - \bar{r}_i| = \alpha_0 + \alpha_1 D_t + \varepsilon_{it} \tag{1}$$

where D_t takes the value 1 for Wednesdays and 0 otherwise during the first four subperiods but takes the value 1 for Thursdays during the last subperiod (0 otherwise). We estimate equation (1) using stacked across-days regressions for each of the five-minute intervals within the day for each subperiod. The estimated coefficients for α_1 are plotted in Figure 5 by intraday time interval for each of the subperiods. Panel A of Figure 5 presents the results for the first subperiod. The plot indicates that all of the estimated coefficients are close to zero. Individual t tests revealed that none of the coefficients were significantly different from zero at the 0.01 level.[21] These results support our earlier conclusions.

Panels B, C, and D of Figure 5 present plots of the estimated coefficients for the middle three subperiods. First, notice that the Wednesday coefficient estimates for 2:00–2:05 PM are large. Tests for whether these coefficients are equal to zero soundly reject the null hypothesis. The respective t values equal 3.69, 4.71, and 3.97 and all are significant at the 0.01 level. Of equal interest is the pattern illustrated in Panels B, C, and D prior to and following the 2:00–2:05 PM interval. In each subperiod, the estimated coefficients are larger than normal up until the close of the day. The coefficients for all three subperiods are significantly different from zero through 2:35 PM. Panel E presents similar results for the fifth subperiod, during which the report was released at 10:30 AM. The coefficient for the 10:30–10:35 AM period is significantly different from zero (t = 2.76) as are the coefficients up through 11:25 AM. Conversely the 10:30 – 10:35 AM coefficients for the first four subperiods are never significantly different from zero ($t = \{-0.31, 1.12, 0.11, -0.57\}$). Notice that once again volatility persists following the announcement. These results clearly show that not only does volatility increase during the

[21]In order to conserve on space, we do not report the individual t statistics for each estimated coefficient. These results will however be made available to interested readers upon request to the authors.

interval immediately after the storage announcement, high volatility persists for up to 55 minutes under the current announcement process.

We test the robustness of this result using a one-hour period. The Brown-Forsythe Modified Levene test statistics for tests of the null

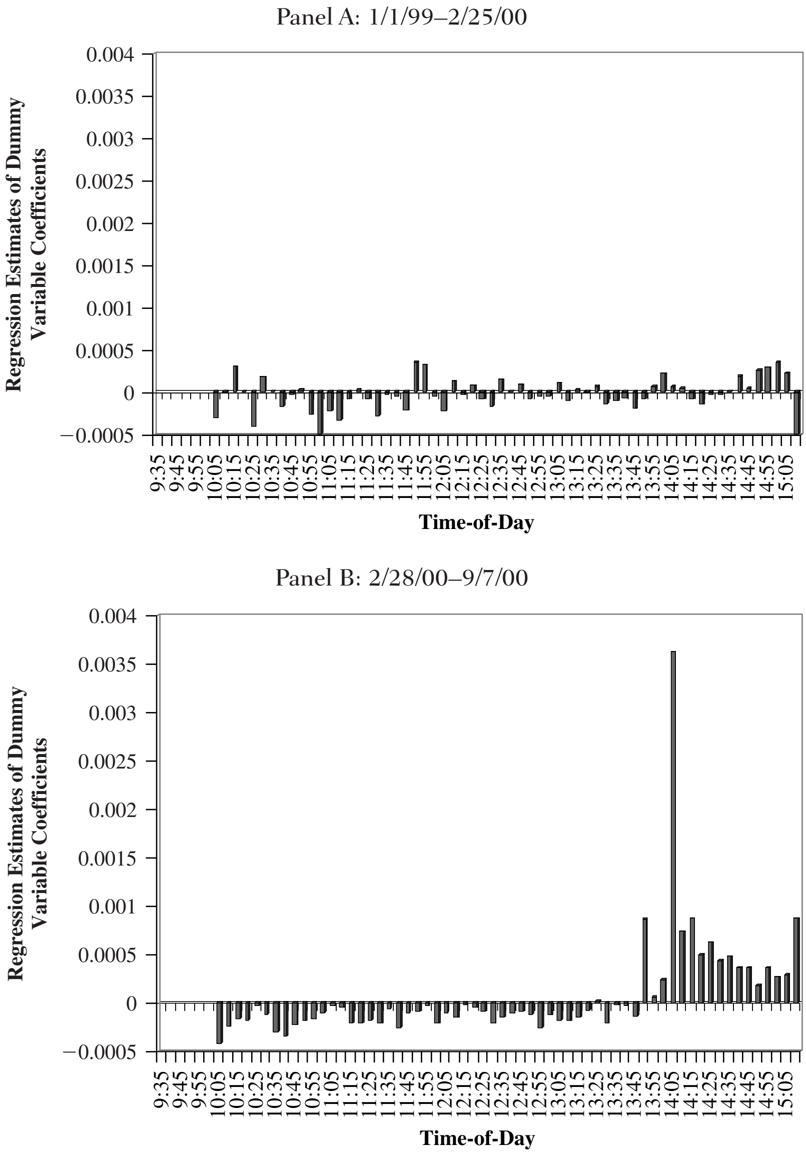
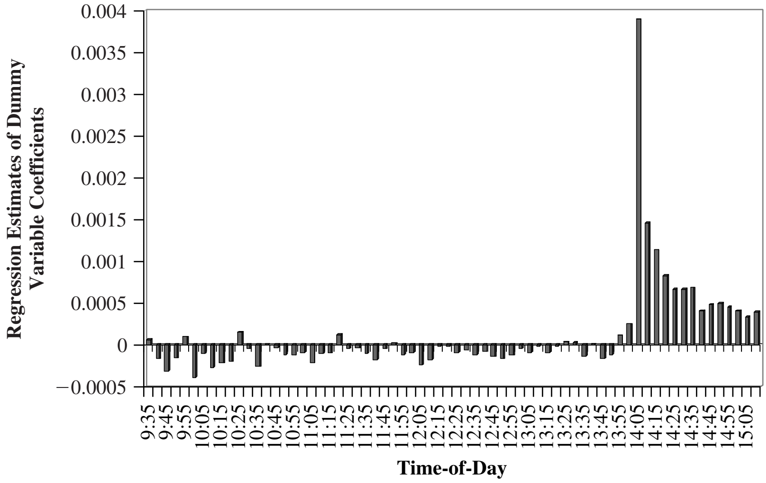


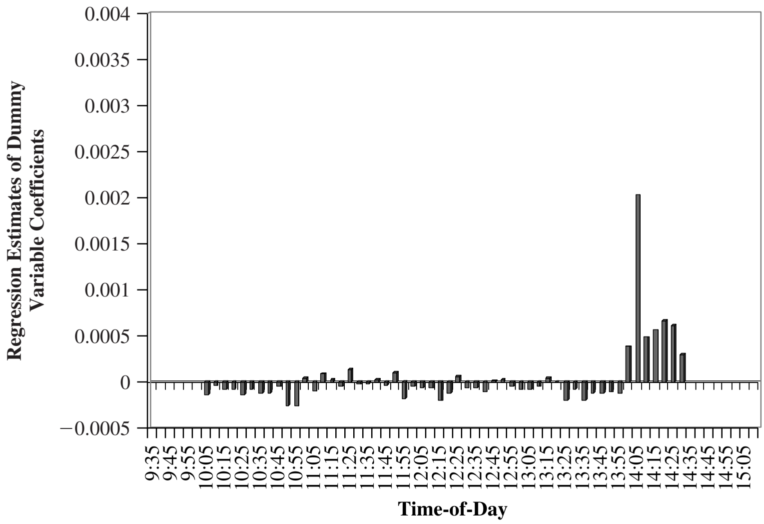
FIGURE 5
Regression estimates of volatility persistence.

Regression estimates of the absolute deviation of the five-minute returns from their interval medians on a dummy variable for Wednesday for each of four subperiods (1/1/99–2/25/2000, 2/28/2000–9/7/2000, 9/8/2000–9/10/2001, 10/8/2001–5/3/2002) and on a dummy variable for Thursday for one subperiod (5/6/2002–10/31/2002). Returns are the ratios of the log prices of the natural gas futures prices for the nearby contract traded on the NYMEX.

Panel C: 9/8/00–9/10/01



Panel D: 10/8/01–5/3/02



Panel E: 5/6/02–10/31/02

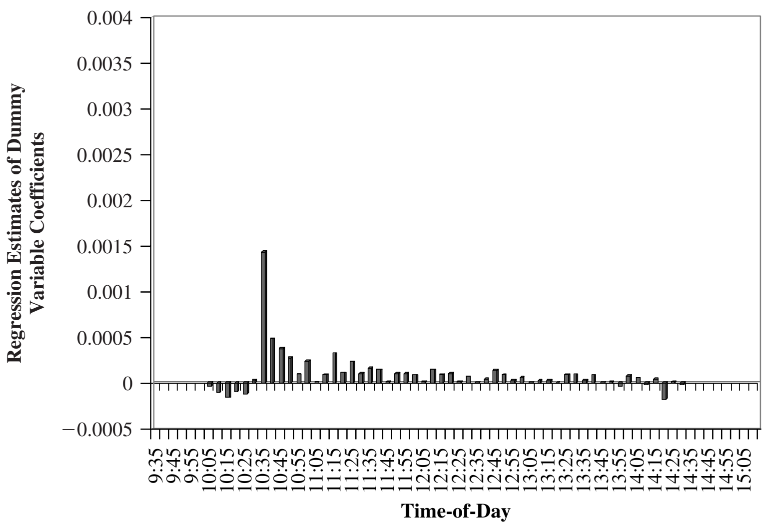


FIGURE 5
(Continued)

hypothesis that volatility over the time interval 1:30–2:30 PM is equal across days of the week are presented in Panel C of Table I. The first row of Panel C presents results across all days of the week. Note that the test does not reject the null hypothesis for the first subperiod, but it is rejected for the next three subperiods. Panel E of Table I reports similar tests only this time we examine the period 10:00 AM–11:00 AM, including and excluding all Thursdays. The first row of Panel E shows that the test rejects the null for each of the last four subperiods. However, the last subperiod during which the EIA report was released at 10:30 AM has a test statistics that is much larger than any of the other subperiods. When Thursdays are excluded the test statistic for the last subperiod does not lead to rejection of the null. We attribute the significance of the tests for subperiods two through four to the fact that volatility is generally larger at the beginning of the day, and these subperiods had opening times in the vicinity of 10:00 AM. The key result however is the much larger test statistic for the last subperiod when Thursdays are included. The interpretation of the second row of Panel C is similar.

CONDITIONAL MEAN EFFECTS

The results presented in the prior sections are based upon the assumption that the mean percentage change in price for intraday time interval i is equal to a constant across the calendar days within each subperiod. In this section, we explore the effects of relaxing this assumption to account for mean effects due to the day of the week and separately for the actual change in the level of gas in storage.[22]

Define $D_M = 1$ if the day of the week is Monday and 0 otherwise. Corresponding dummy variables are defined for Tuesday, Thursday, and Friday.

The results shown in Figure 1 indicate that prices appear to be more volatile around the time that the Gas Storage Report is released. We are interested in whether the Storage Report causes traders to react in a heterogeneous fashion. If there is a temporary shift in the mean when the Storage Report is announced, our assumption of a constant mean during the announcement time interval across days would be inappropriate. Further, the mean shift, if unaccounted for directly, could lead to an incorrect interpretation about whether volatility increases.

[22]Numerous spot and futures markets are known to exhibit day-of-the-week effects.

Suppose also that the percentage change in price during an announcement interval on day t is characterized by a mean that depends upon any surprises revealed by the storage report. Each week, the net change in underground storage ΔS_t is reported along with the actual level in storage S_t for that week and for the prior week S_{t-1}. Now suppose that ΔS_t is in general not a constant from week to week so that the mean on any announcement day t is dependent upon the storage information released on that day. The distribution is therefore shifting from week to week. We control for these shifts in order to obtain a clearer picture of volatility.

We measure the expectation of S_t held at $t - 1$ as

$$E[S_t] = S_{t-1} + \Delta S_{t-1}$$

In other words, the expectation of the change in storage for period t is ΔS_{t-1}. The actual level of S_t is given by

$$S_t = S_{t-1} + \Delta S_t$$

Consequently the surprise in the underground storage report is given by

$$S_t - E[S_t] = (S_{t-1} + \Delta S_t) - (S_{t-1} + \Delta S_{t-1}) = \Delta S_t - \Delta S_{t-1} = DS_t$$

We account for mean day-of-the-week effects and storage report effects by estimating the following models:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_{Th} D_{Th} + \beta_F D_F + \varepsilon_{i,t} \quad (2)$$

$$r_{W,\theta,t} = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_{Th} D_{Th} + \beta_F D_F + \beta_{Storage} DS_t + \varepsilon_{i,t} \quad (3)$$

where $r_{i,t} = \ln(P_{i,t}/P_{i-1,t})$, and $\theta = \{$2:00–2:05, 2:05–2:10, 2:10–2:15$\}$; for the first four subperiods and $\theta = \{$10:30–10:35, 10:35–10:40, 10:40–10:45$\}$; for the last subperiod. Equation (2) is estimated for the first four calendar subperiods and time intervals and all days except the five-minute intervals during the time period 2:00–2:15 PM on Wednesdays, for which we estimate equation (3) to account for any mean shifts due to the storage report surprise. The storage report occurs only on Wednesday, so by default the dummy variables for Monday, Tuesday, Thursday, and Friday take the value 0 in equation (3). A similar system is estimated for the fifth calendar subperiod except we account for the 10:30 AM Thursday announcement instead of the 2:00 PM Wednesday announcement. The variable DS_t is the storage surprise, as already mentioned. The point of this exercise is to obtain measures of the behavior of the percentage price changes that control for conditional mean effects. Differences in variability across intraday time intervals will therefore be revealed by a comparison of the variability of the estimated errors $\varepsilon_{i,t}$ for each interval i.

Estimation Methods

Two alternative methods are used to estimate equations (2) and (3). Under the assumption that the returns across time intervals within the day are uncorrelated, least squares estimation of the single equations one at a time is efficient. Autocorrelation across days for any particular interval could be taken into account in the single equation estimation. Call the maintained statistical structure under these conditions H1. The residuals from each individual model yield an estimated residual standard deviation. These standard deviations can then be examined across intraday time intervals.

Conversely, suppose that the errors are correlated across intervals within the day, possibly in some unknown manner, and that the returns within any interval are correlated across days. Further, for generality, we allow the variances to depend upon the day of the week and the storage surprise as well. Call the maintained statistical structure under these conditions H2. We specify this hypothesis in the following manner:

$$r_{i,t} = \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \beta_F D_F + \beta_{Storage} DS_t + \varepsilon_{i,t} \tag{4}$$

$$\begin{aligned}(r_{i,t} - (\beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \beta_F D_F + \beta_{Storage} DS_t))^2 \\ = \sigma_M^2 D_M + \sigma_T^2 D_T + \sigma_W^2 D_W + \sigma_{Th}^2 D_{Th} + \sigma_F^2 D_F + \sigma_{Storage}^2 (DS)_t^2 + \xi_{i,t}\end{aligned} \tag{5}$$

A separate pair of equations is assumed to describe the behavior of returns within each intraday time interval. There are therefore 68 pairs of equations. We estimate all pairs of equations jointly by Generalized Method of Moments allowing for cross-sectional and time-series correlation.[23] Estimates of the variances of the $\xi_{i,t}$ are a byproduct of the full estimation and reflect the variation within the intraday intervals not accounted for by the control variables.

Figures 6, 7, and 8 present plots of the intraday standard deviations of the errors estimated under the two maintained statistical hypotheses H1 (labeled Std Dev) and H2 (labeled Std Dev by GMM) for the first

[23]The structure of the model is very much like a model estimated by Sheikh and Ronn (1994) in their study of the intraday behavior of returns on financial options. They were concerned with general return behavior.

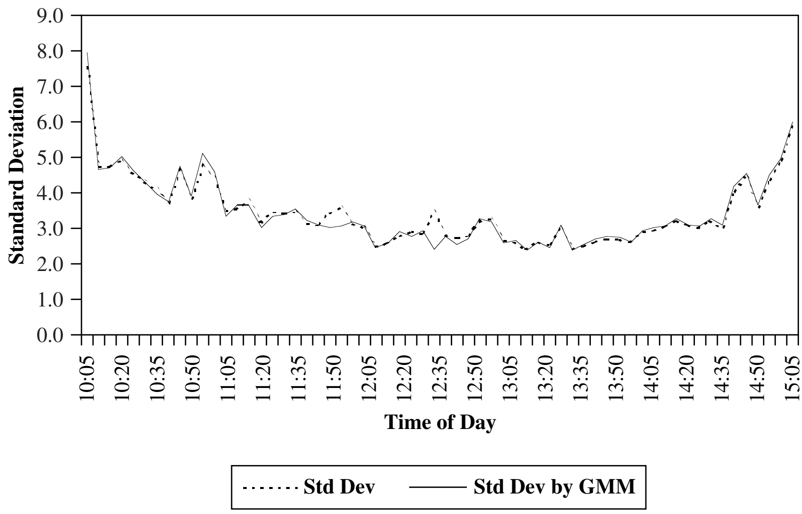


FIGURE 6

Residual standard deviations ($\times 10^3$) of the five-minute intervals within the day for the nearby natural gas futures contract traded on the NYMEX after controlling for day-of-the-week effects and the effects of information contained in the change in natural gas in underground storage as reflected in the American Gas Association Gas Storage Report. The sample period for the graph includes 1/1/99–2/25/2000. Two series are plotted. The first, labeled "Std Dev," is the residual standard deviation computed from the following regression for each time interval separately for all intervals except 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \varepsilon_{i,t}$$

and for the intervals 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \beta_S DS_t + \varepsilon_{i,t}$$

where D_M, D_T, D_W and D_{Th} are day-of-the-week dummies and DS_t represents the surprise in the AGA underground gas storage report when the report is announced during trading hours on Wednesday, where the surprise is relative to the last announced undergraduate storage report.

The second series, labeled "Std Dev by GMM," are the standard deviations directly estimated from the application of Generalized Method of Moments estimation to the system of equations (4) and (5) presented in the text. Equations (4) and (5) specify a hypothesis that the percentage change in the price of the nearby natural gas futures price and its variance depends upon the day-of-the-week and the surprise in the AGA underground gas storage report. Correlation between returns during the day as well as any correlation of returns across days is accounted for in the GMM estimation.

four calendar subperiods.[24] Figure 6 presents the results for the sample period January 1, 1999 through February 25, 2000. The plots in Figure 6 have the same form as the plot shown in Figure 1. Further, the standard deviations from the two estimation procedures are not materially

[24]While the application of GMM to this problem buys us something in terms of accounting for unknown covariance and autocorrelation structures, it comes at a cost. In order to estimate the system, given the number of observations available, we must restrict the intraday time interval equations so that each has the same set of coefficients. Without this restriction, there are too many parameters relative to the number of observations. Figures 7 through 9 suggest that this assumption is innocuous. The instruments used in the GMM estimation are the lagged values of the dependent variable.

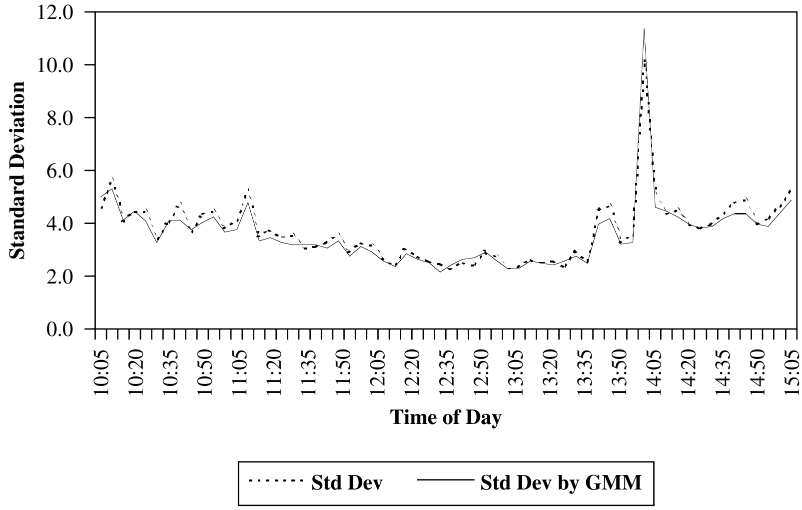


FIGURE 7

Residual standard deviations ($\times 10^3$) of the five-minute intervals within the day for the nearby natural gas futures contract traded on the NYMEX after controlling for day-of-the-week effects and the effects of information contained in the change in natural gas in underground storage as reflected in the American Gas Association Gas Storage Report. The sample period for the graph includes 2/28/2000–9/10/2001. Two series are plotted. The first, labeled "Std Dev," is the residual standard deviation computed from the following regression for each time interval separately for all intervals except 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \varepsilon_{i,t}$$

and for the intervals 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \beta_S DS_t + \varepsilon_{i,t}$$

where D_M, D_T, D_W and D_{Th} are day-of-the-week dummies and DS_t represents the surprise in the AGA underground gas storage report when the report is announced during trading hours on Wednesday, where the surprise is relative to the last announced undergraduate storage report.

The second series, labeled "Std Dev by GMM," are the standard deviations directly estimated from the application of Generalized Method of Moments estimation to the system of equations (4) and (5) presented in the text. Equations (4) and (5) specify a hypothesis that the percentage change in the price of the nearby natural gas futures price and its variance depends upon the day-of-the-week and the surprise in the AGA underground gas storage report. Correlation between returns during the day as well as any correlation of returns across days is accounted for in the GMM estimation.

different.[25] The estimated standard deviations shown in Figures 7–9 are likewise very similar to the plots shown in Figure 1. The estimation procedure has no material influence on the estimated standard deviations. In particular, the sharp spikes in volatility around the time the storage

[25]The Durbin-Watson statistics associated with each of the interval equations estimated under H1 by linear regression never led to rejection of the null hypothesis of zero first-order autocorrelation.

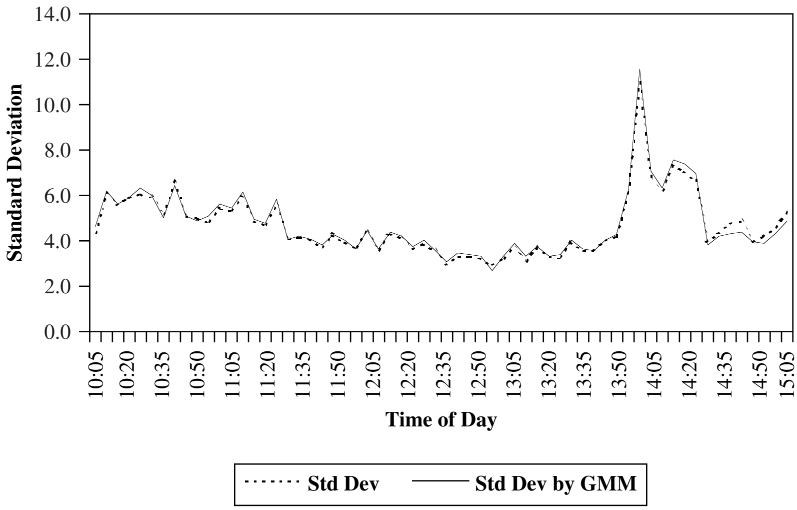


FIGURE 8

Residual standard deviations ($\times 10^3$) of the five-minute intervals within the day for the nearby natural gas futures contract traded on the NYMEX after controlling for day-of-the-week effects and the effects of information contained in the change in natural gas in underground storage as reflected in the American Gas Association Gas Storage Report. The sample period for the graph includes 10/8/2001–5/3/2002. Two series are plotted. The first, labeled "Std Dev," is the residual standard deviation computed from the following regression for each time interval separately for all intervals except 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \varepsilon_{i,t}$$

and for the intervals 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \beta_S DS_t + \varepsilon_{i,t}$$

where D_M, D_T, D_W and D_{Th} are day-of-the-week dummies and DS_t represents the surprise in the AGA underground gas storage report when the report is announced during trading hours on Wednesday, where the surprise is relative to the last announced undergraduate storage report.

The second series, labeled "Std Dev by GMM," are the standard deviations directly estimated from the application of Generalized Method of Moments estimation to the system of equations (4) and (5) presented in the text. Equations (4) and (5) specify a hypothesis that the percentage change in the price of the nearby natural gas futures price and its variance depends upon the day-of-the-week and the surprise in the AGA underground gas storage report. Correlation between returns during the day as well as any correlation of returns across days is accounted for in the GMM estimation.

report is announced suggest that even after accounting for day-of-the-week effects as well as the surprise in the storage report, the market reflects considerable differences of opinion about the implications of the storage information. We also fit the ΔS_t series to an optimal ARMA specification and computed the implied errors. These errors were then used in place of the DS_t in the estimated models. The results regarding the

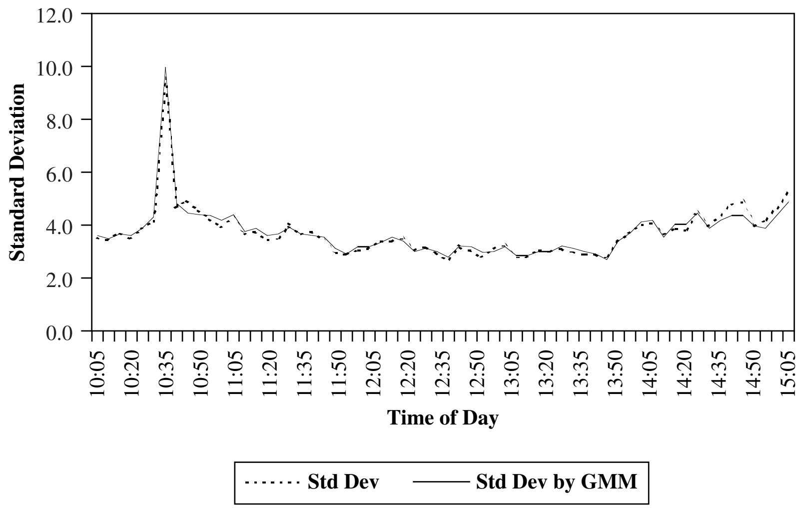


FIGURE 9

Residual standard deviations ($\times 10^3$) of the five-minute intervals within the day for the nearby natural gas futures contract traded on the NYMEX after controlling for day-of-the-week effects and the effects of information contained in the change in natural gas in underground storage as reflected in the Energy Information Administration Gas Storage Report. The sample period for the graph includes 5/6/2002–10/31/2002. Two series are plotted. The first, labeled "Std Dev," is the residual standard deviation computed from the following regression for each time interval separately for all intervals except 10:30–10:35 AM, 10:35–10:40 AM, 10:40–10:45 AM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \varepsilon_{i,t}$$

and for the intervals 2:00–2:05 PM, 2:05–2:10 PM, and 2:10–2:15 PM:

$$r_{i,t} = \ln(P_{i,t}/P_{i-1,t}) = \beta_0 + \beta_M D_M + \beta_T D_T + \beta_W D_W + \beta_{Th} D_{Th} + \beta_S DS_t + \varepsilon_{i,t}$$

where D_M, D_T, D_W and D_{Th} are day-of-the-week dummies and DS_t represents the surprise in the AGA underground gas storage report when the report is announced during trading hours on Wednesday, where the surprise is relative to the last announced undergraduate storage report.

The second series, labeled "Std Dev by GMM," are the standard deviations directly estimated from the application of Generalized Method of Moments estimation to the system of equations (4) and (5) presented in the text. Equations (4) and (5) specify a hypothesis that the percentage change in the price of the nearby natural gas futures price and its variance depends upon the day-of-the-week and the surprise in the AGA underground gas storage report. Correlation between returns during the day as well as any correlation of returns across days is accounted for in the GMM estimation.

volatility of the errors were largely unaffected by this modification and so are not reported.[26]

We conclude that the observed behavior in volatility is not due to a misspecification of the mean used in computing the standard deviation. In other words, we conclude participants in these markets have considerable

[26]The results are available upon request to the authors.

differences of opinion about the implications of surprises in the storage numbers.

SUMMARY AND CONCLUSIONS

The market for natural gas in North America has become an increasingly important element of the economic landscape, especially in light of the pace of deregulation of the electricity-generating sector and the considerable daily trading activity of spot gas and natural gas futures that we currently observe. At the same time natural gas prices have exhibited high variability. Electric utilities, as well as major industrial users of natural gas, face increasing cash flow risk because of the variation in the price of this raw material. But equally important, natural gas traders, an integral part of the overall market, hold large positions that are at risk especially to short-run price volatility. In this paper, we seek to gain an initial understanding of the determinants of short-term natural gas price volatility. We explore the short-term volatility of natural gas prices through an examination of the intraday prices of the nearby natural gas futures contract traded on the New York Mercantile Exchange. Intraday spot prices are not available to us. We are, in particular, interested in the influence of what many regard as a key element of the information set that influences the natural gas market: the Weekly Gas Storage Survey report historically compiled and issued by the American Gas Association, but which has now been taken over by the U.S. Energy Information Administration.

Our findings indicate that the volatility of natural gas futures prices varies both within the day and across days of the week. We show that volatility is high at the beginning of the day, tends to fall, and then rises towards the end of the day. More importantly however, we show that volatility around the time that the gas storage report is released is considerably greater than normal. This is supported by an analysis of three separate regimes during which a different practice was followed regarding the release of the gas storage report: (1) a period during which the AGA issued the storage report after the close of trading on the NYMEX, (2) a period during which the report was issued by the AGA during the day on Wednesday, and (3) a period during which the report was released by the EIA during the day on Thursday. Volatility at the time of the announcement while the market was open is large and persists up to 30 minutes after the announcement. In comparison, volatility during the same time intervals (2:00–2:15 PM or 10:30–10:35 AM) during the period when the report was issued following the close of trading, is not significantly different from volatility in the surrounding intraday periods. We show that these results are not due to a misspecification of the mean or to correlation between returns during the day or across days, by estimating models that account for both day-of-the-week mean effects as well as the surprise reflected in the gas storage report and also account for unknown correlation relations.

Our results represent a step in the direction of gaining an increased understanding of what determines price volatility in the natural gas market and thus should be of interest to both practitioners who trade in this market as well as to academics interested in the behavior of this market and energy markets in general. The analysis of short-term volatility leads naturally to the question of what determines shifts in volatility in the natural gas market over the medium to long-term. The results suggest that considerable heterogeneity exists in the interpretation of key data describing the state of the market. A fruitful enterprise will be to examine how differences of opinion influence the level of volatility over longer periods of time, an issue we are in the early stages of investigating.

APPENDIX A

Weekly American Gas Storage Survey

Published July 20, 2001[27] by the American Gas Association.

Report of Estimated U.S. Working Gas Levels In Underground Storage as of 9:00 AM Friday. Week Ending July 20, 2001

	Estimated Working Gas in Storage			
	This Week (Bcf)	*Last Week (Bcf)*	*Change (Bcf)*	*Percent Full (5)*[31]
Producing Region[28]	621	608	+13	65%
Consuming Region East[29]	1,143	1,083	+60	62%
Consuming Region West[30]	362	351	+11	72%
Total U.S.	2,126	2,042	+84	65%

			Working Gas in Underground Storage	
	Survey Sample Percent[32]	*Estimated Full (Bcf)*	*Same Wk Yr Ago*	*Prior Five-Yr Avg.*
Producing Region[28]	78%	953	468	553
Consuming Region East[29]	94	1,835	1,019	1,074
Consuming Region West[30]	76	506	370	336
Total U.S.	86%	3,294	1,857	1,962

Note. This report has been prepared based on information gathered and aggregated by the American Gas Association. Neither the American Gas Association nor its members make any warranty or representation, express or implied, with respect to the accuracy, completeness or usefulness of this data. Normal distribution of the American Gas Storage Survey is initiated each Wednesday between 2:00–2:15 PM Eastern Time. If for any reason AGA is closed on Wednesday (the normal reporting day), the storage report will be distributed on the next business day that AGA is officially open for business between 2:00–2:15 PM. Business closings can be determined by calling (202) 824-7000. Questions regarding this report should be directed to Chris McGill (202) 824-7132.

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[27]A complete explanation of AGA's methodology for this report can be found in AGA Issue Brief 2000–01, "American Gas Storage Survey Procedures and Methodology." Copies of the Issue Brief can be obtained by calling (202) 824–7126.

[28]Includes Texas, Oklahoma, Kansas, New Mexico, Louisiana, Arkansas, Mississippi and Alabama.

[29]Includes all states east of the Mississippi River except Alabama and Mississippi, plus Iowa, Nebraska, and Missouri.

[30]Includes all states west of the Mississippi River except the Producing Region and Iowa, Nebraska, and Missouri.

[31]This Week regional and Total U.S. volumes divided by Estimated Full regional and Total U.S. volumes. This statistic is intended to show how "full" working gas is at any given time.

[32]This percentage value describes the survey sample size each week (sample may change if companies fail to report or a company is added to the weekly survey). It is determined by dividing the maximum volume held in recent years in reported pools for all the reporting companies in a given region for that week by that region's estimated full. Any additions to the sample or failures to report are reflected in a percentage change from the prior week.

APPENDIX B

Weekly Natural Gas Storage Report

Released January 3, 2003 by the U.S. Energy Information Administration for the week ending December 27, 2002.

Region	*Stocks (Bcf) for December 27, 2002*	*Stocks (Bcf) for December 20, 2002*	*Implied Net Change (Bcf)*	*Year Ago Stocks (Bcf)*
East	1,400	1,468	−68	1,730
West	353	379	−26	363
Producing	664	693	−29	895
Total Lower 48	2,417	2,540	−123	2,989

Region	*Five-Year (1997–2001) Average Stocks (Bcf)*	*Difference from Five-Year Average (Percent)*	*Survey Sample Coverage (Percent)*[33]	*Estimated Std. Error for Current Week Working Gas Stock (Bcf)*[34]
East	1,528	−8.4	90	39
West	307	15.0	92	32
Producing	677	−1.9	89	17
Total Lower 48	2,512	−3.8	90	54

Note. The complete documentation of EIA's estimation methodology is available in the report, *Methodology for EIA Weekly Underground Natural Gas Storage Estimates* (May 2002).

The weekly storage regions are:

East Region (Illinois, Indiana, Iowa, Kentucky, Maryland, Michigan, Missouri, Nebraska, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia)

West Region (California, Colorado, Minnesota, Montana, Oregon, Utah, Washington, and Wyoming)

Producing Region (Alabama, Arkansas, Kansas, Louisiana, Mississippi, New Mexico, Oklahoma, and Texas)

The Weekly Natural Gas Storage Report released by the EIA is a public domain document and is located at <http://tonto.eia.doe.gov/oog/info/ngs/ngs.html>.

[33] For each region, the sample coverage is the ratio of working gas in underground storage operated by respondents to the weekly survey relative to total working gas in underground storage for that month. It is based on the most recent monthly survey of all underground storage fields. The sample coverage may vary if companies fail to report or the sample population changes.

[34] Weekly estimates of working gas are subject to sampling error because they are based on a sample of the population. Sixty-eight percent of the time, the volume that would have been obtained from a complete census of all storage operations will lie between the estimated volume and plus or minus one standard error. See Methodology for EIA Weekly Underground Natural Gas Storage Estimates for a description of its calculation.

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