Original Article

Did Amaranth's absolute, relative and extreme positions affect natural gas futures prices, spreads and volatilities?

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ABSTRACT Amaranth Advisors LLC (Amaranth) suffered losses of \$6.4 billion and failed in September 2006 as a result of its enormous spread trade bets in the natural gas futures markets and uncharacteristically large spread price movements. This financial fiasco led to a Congressional investigation, and, shortly thereafter, Amaranth was charged by the Commodity Futures Trading Commission (CFTC) and Federal Energy Regulatory Commission (FERC) with price manipulation. CFTC charged Amaranth with *attempted, intraday*, price manipulation in the natural gas *futures* market, and FERC charged Amaranth with *perfected, intraday*, price manipulation in the natural gas *spot market*. Marthinsen and Gai expanded the scope of these price manipulation charges by investigating whether Amaranth engaged in *interday* price manipulation during 2006. They found no convincing evidence of one-way Granger causality from changes in Amaranth's absolute positions to changes in the prices of natural gas derivatives contracts. This article expands on the interday price manipulation analysis of Marthinsen and Gai by testing for Granger causality between (1) changes in Amaranth's extreme positions and the returns on natural gas futures contracts, (2) changes in Amaranth's (calendar) spread positions and (calendar) spread prices on natural gas futures contracts, (3) changes in Amaranth's *relative* spread positions and spread prices, and (4) changes in Amaranth's positions and price volatility in the natural gas derivatives markets. Our results show no strong statistical evidence that changes in Amaranth's absolute, relative or extreme

positions had significant effects on natural gas prices, spreads or volatilities. Therefore, this article casts further doubts on claims that Amaranth engaged in interday price manipulation.

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INTRODUCTION

Amaranth Advisors began operations in 2000 as a leveraged, multistrategy hedge fund. Its portfolio was not diversified but rather designed to make concentrated directional and spread bets on the most promising market opportunities. In 2004, the company began trading energy derivatives and, by 2006, these investments had become the majority (58 per cent) of its portfolio. In addition to being a relatively large part of its own investments, Amaranth's natural gas futures positions were also a relatively large part of the open interest on the New York Mercantile Exchange (NYMEX) and InterContinental Exchange (ICE). During 2006, Amaranth held between 46 and 81 per cent of the open interest in the NYMEX's most actively traded natural gas futures contracts.¹

Amaranth's downfall came in 2006. Expecting the US natural gas industry to recover quickly from hurricanes Katrina and Rita (August/September 2005), the fund took massive directional and spread trade positions, betting that natural gas prices would fall until September 2006 and that winter 2007 prices would rise relative to fall 2006 and spring 2007.¹ During August and September 2006, spread prices plunged because of the relatively mild US weather conditions. As a result, Amaranth's spread positions hemorrhaged cash and, losses

mounted. A severe lack of liquidity led to Amaranth's failure and subsequent sale, in September 2006, to JP Morgan and Citadel Investment Group LLC.

About one month after Amaranth's failure (October 2006), the US Senate Permanent Subcommittee on Investigations (PSI) started a nine-month inquiry into the causes and broader regulatory issues connected to this derivatives fiasco. The PSI Report, entitled *Excessive Speculation in the Natural Gas Market*, was published in June 2007 and Congressional hearings followed in late June and early July 2007.^{1,2} The PSI report accused Amaranth of *excessive speculation* that distorted natural gas prices, spreads and market volatilities. On 24 July 2007, the Commodity Futures Trading Commission (CFTC) charged Amaranth with *attempted, intraday* price manipulation in the natural gas *derivatives market*, and one day later the Federal Energy Regulatory Commission (FERC) followed suit by charging Amaranth with *perfected, intraday*, price manipulation in the natural gas *spot market*.

Marthinsen and Gai³ expanded the scope of the CFTC and FERC price manipulation investigations of Amaranth by analyzing whether the fund engaged in *interday* price manipulation. They found no convincing evidence of one-way Granger causality from changes in Amaranth's absolute positions to changes in the prices of

natural gas derivatives contracts. We build on the interday price manipulation work of Marthinsen and Gai by testing for Granger causality between (1) changes in Amaranth's extreme positions and the returns on natural gas futures contracts, (2) changes in Amaranth's (calendar) spread positions and (calendar) spread prices on natural gas futures contracts, (3) changes in Amaranth's *relative* spread positions and spread prices, and (4) changes in Amaranth's positions and price volatility in the natural gas derivatives markets.

This article is divided into five parts. The first section expands the literature review of Marthinsen and Gai by including scholarly contributions that link changes in traders' positions to changes in price volatility. It also explains our data set and some of the limitations that price manipulation studies face in the natural gas futures markets. The next section employs Granger causality tests to analyze whether changes in Amaranth's *extreme* positions had significant effects on natural gas derivatives prices. Along these lines, the subsequent section investigates whether changes in Amaranth's spread positions affected spread prices, and it also tests to see whether changes in Amaranth's spread positions relative to overall open interest affected natural gas spread prices. The penultimate section completes the analysis by testing whether changes in Amaranth's positions had significant effects on the volatility of natural gas futures prices. Finally, the last section offers conclusions and further insights.

LITERATURE REVIEW AND DATA OVERVIEW

Marthinsen and Gai³ included an extensive literature review of the relationship between changes in traders' positions and changes in derivative market prices. As might be expected,

empirical studies of trade-based manipulation in commodity and financial markets have produced conflicting results, and the lack of quality data made comparisons and conclusions hard to draw. Another facet of this debate centers on the relationship between changes in traders' positions and derivative market price volatility.

Bessembinder and Seguin⁴ concluded that a strong, asymmetric, positive relationship exists between unexpected changes in contemporaneous trading activity and volatility, but a strong negative relationship exists between changes in expected open interest and volatility. To broaden the perspective of price manipulation analyses, other studies have tested the relationship between changes in *large trader* positions and changes in the prices and/or volatilities of derivative contracts. Wei and Kim⁵ identified a positive association between *absolute* position values and changes in volatility. Kodres and Pritsker,⁶ Kodres,⁷ and Weiner⁸ explained this relationship by suggesting that large funds often had similar market outlooks and, therefore, took similar positions that reinforced pressures on market prices. Their conclusion was weakened, however, by the relatively small portion (under 10 per cent) of overall price changes accounted for by these transactions. Finally, Irwin and Holt⁹ tapped a unique data set and found a small, positive relationship between the trading volume of large hedge funds and volatility – a relationship the authors attributed mainly to the private information hypothesis.

One of the problems with these *large-trader* studies has been a suspected bias in their conclusions because of the paucity of detailed information. Even very early analyses, which used broker data on relatively small, speculative traders ran into problems when they tried to

generalize their results (see Stewart¹⁰ and Hieronymus¹¹). It is because data on large-trader positions are so difficult to obtain that the US government's release of detailed information on the multibillion dollar implosion of Amaranth in 2006 is so important.¹

The PSI Report provided in-depth information on Amaranth's daily trading activities on the NYMEX and ICE natural gas derivatives markets, which we were able to combine with daily NYMEX market prices and open interest to conduct our analysis. Unfortunately, our investigation could not be extended to ICE because it does not make daily open interest and price data available to the public. From the PSI database, we constructed Amaranth's spread positions for the period from 3 January to 31 August, which corresponds to the interval during which Amaranth had its greatest market power. These particular contracts were the ones in which Amaranth held its largest open interest and also the ones responsible for the hedge fund's failure.

DID AMARANTH'S EXTREME POSITIONS AFFECT PRICES?

To test the effect that changes in Amaranth's extreme positions had on natural gas futures prices, Equation (1) uses the methodology of Wang¹² and Sanders *et al*¹³ to estimate:

$$R_t^c = \alpha_0 + \alpha_1 ES_{t-1}^c + \alpha_2 EL_{t-1}^c + \varepsilon_t \quad (1)$$

Amaranth's relative market power is captured by two dummy variables, EL_t^c and ES_t^c , which represent Amaranth's extreme long and short positions in the natural gas derivatives market as a percent of total open interest. These variables are activated on those days when Amaranth's

market power should have been the greatest. $EL_t^c = 1$ when Amaranth's long position for contract c at time t was greater than 20 per cent of the total open interest on NYMEX; otherwise, $EL_t^c = 0$. Similarly, $ES_t^c = 1$ when Amaranth's short position was greater than 20 per cent of the total open interest on NYMEX; otherwise, $ES_t^c = 0$.

The constant term, α_0 , is the average return rate for contract c during the sample period without the influence of Amaranth's extreme positions. A simple t -test is used to determine whether Amaranth's extreme short positions were significant and, thereby, changed the mean return rate by α_1 . Similarly, tests are conducted to determine whether Amaranth's extreme long positions were significant and, thereby, changed the mean return rate by α_2 . The regression output is presented in Table 1. The mean return during the sample period is negative, and, in all cases, there is no evidence that either α_1 or α_2 is significant. Therefore, Amaranth's extreme positions do not appear to have had a significant influence on natural gas futures prices, which weakens suspicions that the fund engaged in interday price manipulation.

DID CHANGES IN AMARANTH'S SPREAD POSITIONS LEAD SPREAD PRICE CHANGES?

Amaranth's three major spread-trade bets were on the January 2007/October 2006, January 2007/November 2006 and March 2007/April 2007 contracts. To determine whether changes in Amaranth's positions led changes in these spread prices, Equation (2) is estimated, following the Granger causality approaches

Table 1: Impact of Amaranth's extreme positions on natural gas futures prices

	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06
Constant	-1.47E-02	-1.23E-02	-9.56E-03	-7.86E-03	-6.18E-03	-2.32E-03	-5.99E-03
<i>t</i> -statistics ^a	[2.481]*	[2.413]*	[2.547]*	[2.441]*	[2.042]*	[0.663]	[1.770]
ES=1	—	1.18E-02	1.31E-02	2.93E-02	1.61E-03	-2.61E-03	—
<i>t</i> -statistics	—	[1.448]	[0.062]	[1.422]	[0.217]	[0.482]	—
EL=1	—	—	1.81E-03	6.36E-04	—	—	7.57E-03
<i>t</i> -statistics	—	—	[1.648]	[0.083]	—	—	[1.372]
Observations	36	59	77	99	120	139	162
<i>R</i> ²	0	0.035	0.035	0.021	0	0.002	0.012
	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07
Constant	-4.55E-03	-3.72E-03	-1.28E-03	-5.89E-03	-8.08E-03	-4.09E-03	-3.56E-03
<i>t</i> -statistics	[1.584]	[0.955]	[0.774]	[1.666]	[1.327]	[1.277]	[2.113]*
ES=1	—	2.00E-03	-6.24E-04	—	—	—	4.57E-03
<i>t</i> -statistics	—	[0.442]	[0.110]	—	—	—	[1.740]
EL=1	3.69E-03	—	—	5.69E-03	7.37E-03	3.75E-03	3.93E-03
<i>t</i> -statistics	[0.559]	—	—	[1.471]	[1.176]	[1.046]	[1.226]
Observations	164	164	164	164	164	164	164
<i>R</i> ²	0.002	0.001	0	0.013	0.008	0.007	0.021

^aAbsolute value of the *t* statistic is in brackets: *significant at 5 per cent; **significant at 1 per cent.

used by Wang,¹² Sanders *et al*¹³ and Hartzmark.¹⁴

$$R_t^s = \alpha + \sum_{i=1}^m \gamma_i R_{t-i}^s + \sum_{j=1}^n \beta_j \Delta ASP_{t-j}^s + \varepsilon_t \quad (2)$$

R_t^s is the return rate for spread *s* at trade date *t*, where $R_t^s = \ln(P_t^s) - \ln(P_{t-1}^s)$. P_t^s is the end-of-day settlement price for spread *s* at trade date *t*, and, finally, ΔASP_{t-j}^s is the first difference of Amaranth's position for spread *s* at time period *t-j*. Sample data are limited to the period from 3 January 2006 to 31 August 2006. The Augmented Dickey-Fuller test is used to verify that spread positions and spread prices are

unit-root stationary and the first difference of the spread positions and return rates are stationary. Akaike's information criterion and Schwarz's information criterion are used to select the order of lags (*m*, *n*). The Durbin-Watson test, Engle's LM test, and Breusch-Godfrey test are performed to ensure there are no first-order and higher-order serial correlations in the residuals.

The lag orders for these spread trades are surprisingly short, indicating that information more than a couple days old is not useful for forecasting changes in spread returns. Moreover, with the exception of one contract (January 2007/November 2006), there are no significant lead-lag relationships, indicating

Table 2: Granger causality test between Amaranth's spread positions and spread prices
3 January 2006 to 31 August 2006

	<i>Amaranth's spread position changes lead spread returns</i>		
	<i>Jan07/Oct06 spread</i>	<i>Jan07/Nov06 spread</i>	<i>Mar07/Apr07 spread</i>
Lags: $(m, n)^a$	(1, 1)	(1, 2)	(1, 1)
Impact ^b	5.81E-07	5.58E-06	-2.80E-06
Observations	155	149	155
R^2	0.001	0.0773	0.0067
P -value ^c	0.6995	0.0049**	0.4798

^aThe lag orders (m, n) for $R_t^s = \alpha + \sum_{i=1}^m \gamma_i R_{t-i}^s + \sum_{j=1}^n \beta_j \Delta ASP_{t-j}^s + \varepsilon_t$ are based on AIC and SIC.

^bThe cumulative impact of Amaranth spread position changes is calculated as $\sum_{j=1}^n \beta_j$.

^cThe P -value from a Wald test of the null hypothesis that β_j is jointly zero: *significant at 5 per cent;

**significant at 1 per cent.

that Amaranth's position changes did not lead price movements (see Table 2).

For the January 2007/November 2006 contract, the cumulative impact of Amaranth's positions on the spread price is positive and significant. For example, the cumulative impact of a 1000-contract increase in Amaranth's spread position increased the spread price by 0.558 per cent, but this result is sensitive to the sample period. If the interval were truncated to cover only 3 January 2006 to 28 April 2006 (that is, the period during which Amaranth generated its highest spread-trade returns), the cause-and-effect relationship becomes insignificant, with a P -value of 0.9431.

Did Amaranth's relative spread positions affect prices?

Amaranth's purchases and sales would not have been an issue if its trades were offset by other large counterparties (commercial or

non-commercial). During 2005/2006, there were approximately 200 large traders of natural gas futures contracts on NYMEX.¹⁵ Every futures contract has a buyer and a seller. Therefore, if Amaranth controlled a dominant portion of the open interest on one side of a futures contract (for example, 81 per cent of the buy orders for the December 2006 contract), then its market power would depend on the size and motivation of the counterparties to these trades. For example, if equally large hedge funds with different views of the market were on the other side of Amaranth's transactions, or if counterparties were commercial traders intent on hedging positions to secure future profits, or if Amaranth traded with relatively small traders out to make speculative gains, then price manipulation would not be an issue. Amaranth would simply be providing needed liquidity for these other traders.¹⁶

Despite the vast amount of information provided by the PSI Report, its data set was not

supplemented by the positions of commercial and other non-commercial trading parties, who could have been neutralizing Amaranth's potential market power. Moreover, only abridged information from CFTC's Large Trader Reporting Program is available from the Commitment of Traders Report, and these data are at such a high level of aggregation and low level of periodicity (weekly) that it is virtually impossible to determine the market power exerted by an individual trader, such as Amaranth. Therefore, any proxy variable that represents a trader's relative market power is bound to be second best.¹⁷

Owing to the lack of detailed information, the variable, $\Delta ASP_t^s \times \left| \frac{ASP_t^s}{0.5x(OI_t^{s1} + OI_t^{s2})} \right|$, is introduced to capture Amaranth's relative size in the natural gas futures market. ASP_t^s is Amaranth's spread position at time t for spread s ; and OI_t^{s1} and OI_t^{s2} are the market open interest at time t for, $s1$ and $s2$, which are the two contracts that comprise the spread trade (for example, the October 2006 and January 2007 natural gas futures contracts). This ratio helps to shed light on the issue of price manipulation. Equation (3) relates the return on

NYMEX-traded spread contract s at time t , (R_t^s) , to the lagged values of these returns and also to the aforementioned customized market-power ratio.

$$\Delta R_t^s = \alpha + \sum_{i=1}^m \gamma_i R_{t-i}^s + \sum_{j=1}^n \beta_j \Delta ASP_{t-j}^s \times \left| \frac{ASP_{t-j}^s}{0.5x(OI_{t-j}^{s1} + OI_{t-j}^{s2})} \right| + \varepsilon_t \quad (3)$$

Table 3 shows the results of this analysis, which indicate P -values for these contracts well below meaningfully significant levels. Therefore, Amaranth's spread positions relative to total open interest in the NYMEX futures market appear to have had no significant impact on the spread price of natural gas futures contracts.

DID AMARANTH'S POSITION CHANGES AFFECT VOLATILITY?

A final issue dealing with Amaranth's relative market power in the futures markets is whether the fund increased the price volatility of natural gas futures contracts. Market volatility has

Table 3: Impact of Amaranth's relative spread positions on spread prices

	Jan2007/Oct 2006	Jan 2007/Nov 2006	Mar 2007/Apr 2007
Lags: $(m, n)^a$	(1,2)	(1,2)	(1,1)
Impact ^b	9.80E-07	1.02E-05	-9.32E-06
Observations	149	149	155
R^2	0.0109	0.0304	0.0078
P -value ^c	0.453	0.1772	0.4138

^aThe lag orders (m, n) for $R_t^s = \alpha + \sum_{i=1}^m \gamma_i R_{t-i}^s + \sum_{j=1}^n \beta_j \Delta ASP_{t-j}^s + \varepsilon_t$ are based on AIC and SIC.

^bThe cumulative impact of Amaranth spread position changes is calculated as $\sum_{j=1}^n \beta_j$.

^cThe P -value from a Wald test of the null hypothesis that β_j is jointly zero: *significant at 5 per cent; **significant at 1 per cent.

important consequences for hedgers, regulators and other investors because it affects hedging costs and hedging effectiveness. In the face of rising volatilities, investors alter their portfolios in reaction to changing risk-return incentives. Similarly, regulators worry that increased volatility in futures markets might spill over to the real economy, thereby reducing growth, increasing unemployment and rendering the financial system less effective.

To test whether Amaranth's large positions increased market volatility, the three measures of volatility in Chatrath *et al*¹⁸ are employed:

- Inter-day price variability = $\frac{|P_t^c - P_{t-1}^c|}{P_{t-1}^c}$, where P_t^c is the end-of-the-day futures price for contract c at trade date t ;
- Intraday price variability = $\frac{(P_t^{Hc} - P_t^{Lc})}{(0.5) \times (P_t^{Hc} + P_t^{Lc})}$, where P_t^{Hc} , P_t^{Lc} are the high and low price levels, respectively, for contract c at time t , and
- Adjusted price range = $\frac{(P_t^{Hc} - P_t^{Lc}) + (P_{t-1}^{Lc} - P_{t-1}^{Hc})}{(0.5) \times (P_t^{Hc} + P_t^{Lc})}$, if $P_t^{Lc} > P_{t-1}^{Hc}$; $\frac{(P_t^{Hc} - P_t^{Lc}) + (P_{t-1}^{Hc} - P_{t-1}^{Lc})}{(0.5) \times (P_t^{Hc} + P_t^{Lc})}$, if $P_{t-1}^{Lc} < P_t^{Hc}$; $\frac{(P_t^{Hc} - P_t^{Lc})}{(0.5) \times (P_t^{Hc} + P_t^{Lc})}$ otherwise. The advantage of this measure is that it captures overnight changes in prices that would not be reflected in intraday price variability.

To analyze the contemporaneous relationship between price variability and Amaranth's relative positions, the correlation between σ_t^c and $\left| \frac{\Delta AP_{t-j}^c}{\Delta OI_{t-j}^c} \right|$ is calculated, where the range of σ_t^c is measured by the three aforementioned price variability measures. $|\Delta AP_t^c|$ is the absolute value of the change in Amaranth's position at time t for contract c , and $|\Delta OI_t^c|$ is the absolute value of the change in market open interest at time t for contract c . Table 4 lists the contemporaneous

correlation coefficients and the corresponding P -values of two-tailed t -tests, which show that none of the contract months has a significant correlation at the 1 per cent level.

To examine the influence of Amaranth's changing positions on price variability, equation (4) is estimated:

$$\sigma_t^c = \alpha + \sum_{i=1}^m \gamma_i \sigma_{t-i}^c + \sum_{j=1}^n \beta_j \left| \frac{\Delta AP_{t-j}^c}{\Delta OI_{t-j}^c} \right| + \varepsilon_t \quad (4)$$

Table 5 presents the output and Wald coefficient tests for the null hypothesis that β_j is jointly zero. As was the case in previous analyses, there is no empirical evidence that changes in Amaranth's positions had significant impacts on the three measures of price variability.

CONCLUSIONS

Amaranth's failure appears to be an implosion rather than an explosion because it affected shareholders, investors and employees rather than the broader financial markets. According to CFTC Commissioner Annette L. Nazareth, despite losing US\$6.4 billion, Amaranth's failure had 'no significant effects on the markets from a systemic risk point of view'.¹⁹ Fund's investment strategies seemed to have been fully understood by upper management; it met all margin and collateral requirements, and obeyed any and all NYMEX directives. Amaranth was not rescued by the US government or Federal Reserve, but rather it was purchased by JP Morgan and Citadel. Moreover, there is no apparent evidence of rogue trader fraud or embezzlement.

If Amaranth had increased natural gas futures prices, then consumers could have been hurt,

Table 4: Contemporaneous relationship between price variability and Amaranth's relative position

<i>Contract date</i>	<i>Correlation coefficient</i>	<i>P-value</i>	<i>Contract month</i>	<i>Correlation coefficient</i>	<i>P-value</i>
<i>Inter-day price variability</i>					
Mar-06	-0.1494	0.3989	Oct-06	-0.0269	0.7352
Apr-06	-0.1006	0.4566	Nov-06	0.1406	0.0752
May-06	0.2196	0.0583	Dec-06	-0.0842	0.2884
Jun-06	-0.0151	0.8832	Jan-07	0.041	0.6052
Jul-06	-0.1082	0.2458	Feb-07	-0.0151	0.8487
Aug-06	-0.1305	0.1299	Mar-07	0.1071	0.1777
Sep-06	0.0053	0.9468	Apr-07	-0.1091	0.1683
<i>Intra-day price variability</i>					
Mar-06	-0.1257	0.4789	Oct-06	-0.077	0.3318
Apr-06	-0.031	0.8188	Nov-06	0.185★	0.0188
May-06	0.1702	0.1443	Dec-06	0.0144	0.8565
Jun-06	-0.0389	0.7055	Jan-07	-0.0084	0.916
Jul-06	0.0019	0.9836	Feb-07	0.0758	0.339
Aug-06	-0.0447	0.6055	Mar-07	0.0235	0.7676
Sep-06	0.0722	0.366	Apr-07	0.0439	0.5806
<i>Adjusted price change</i>					
Mar-06	-0.1326	0.4547	Oct-06	-0.0664	0.4029
Apr-06	-0.0464	0.7315	Nov-06	0.1931★	0.0141
May-06	0.2646★	0.0218	Dec-06	0.0018	0.9821
Jun-06	-0.0438	0.6704	Jan-07	0.0546	0.4913
Jul-06	-0.01	0.9147	Feb-07	0.0476	0.5489
Aug-06	-0.0467	0.5889	Mar-07	0.0413	0.604
Sep-06	0.0619	0.4384	Apr-07	0.0071	0.9288

★Under two-tailed *t*-test the correlation coefficients are significant at 5 per cent.

and if the fund had increased the natural gas price volatilities, then some businesses may have been harmed because they hedged at artificially high prices. Whether Amaranth manipulated intraday natural gas futures prices is a decision the courts will make. At the time

of writing, no ruling or settlement had been made on the *intraday* price manipulation charges. Our analysis shows no statistical evidence that Amaranth significantly influenced *interday* prices, spread prices or volatilities in the natural gas futures markets.

Table 5: Granger causality test of Amaranth's relative positions' effect on spread price volatility

	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06
<i>Inter-day price variability</i>							
Lags: $(m, n)^a$	(3, 1)	(1, 5)	(1, 5)	(1, 1)	(1, 1)	(1, 1)	(1, 1)
Impact ^b	2.73E-04	1.62E-03	-6.97E-04	1.27E-04	5.80E-04	-1.05E-04	7.40E-04*
Observations	31	44	57	95	114	133	156
R^2	0.202	0.381	0.296	0.02	0.006	0.004	0.035
P -value ^c	0.659	0.949	0.402	0.203	0.419	0.897	0.049
	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07
Lags: (m, n)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 2)
Impact	-2.93E-05	-2.64E-06	-1.88E-04	1.15E-04	-2.98E-04	-6.02E-05	-4.95E-05
Observations	158	158	158	158	158	157	152
R^2	0.006	0.005	0.017	0.01	0.009	0.008	0.04
P -value	0.698	0.949	0.138	0.49	0.577	0.579	0.064
<i>Intra-day price variability</i>							
Lags: (m, n)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)
Impact	-1.63E-04	-3.41E-04	-1.90E-05	1.59E-04	1.31E-03	-2.01E-04	3.55E-04
Observations	31	54	71	93	112	131	154
R^2	0.008	0.036	0.012	0.086	0.108	0.13	0.334
P -value	0.805	0.711	0.733	0.077	0.046	0.772	0.293
	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07
Lags: (m, n)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)	(1, 1)
Impact	3.05E-05	-3.31E-05	-2.07E-04	-3.06E-05	8.11E-05	-7.33E-05	-1.08E-04
Observations	156	156	156	156	156	154	156
R^2	0.257	0.237	0.184	0.155	0.117	0.108	0.119
P -value	0.65	0.367	0.061	0.833	0.863	0.499	0.313

Adjusted price change

Lags: (m, n)	(1,1)	(3,1)	(1,1)	(1,1)	(1,1)	(1,1)	(1,1)	(2,1)
Impact	-2.24E-04	-8.99E-04	-2.38E-05	1.51E-04	1.25E-03	-3.73E-04	3.20E-04	
Observations	31	51	71	93	112	131	154	
R^2	0.006	0.211	0.006	0.056	0.073	0.091	0.313	
P-value	0.75	0.382	0.697	0.118	0.071	0.605	0.372	
	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	
Lags: (m, n)	(2,1)	(2,1)	(1,1)	(1,1)	(1,1)	(1,1)	(1,1)	
Impact	-2.82E-06	-2.12E-05	-2.10E-04	8.29E-05	1.24E-04	-1.02E-04	-1.17E-04	
Observations	156	156	156	156	156	154	156	
R^2	0.272	0.226	0.152	0.144	0.094	0.095	0.119	
P-value	0.968	0.583	0.078	0.591	0.801	0.371	0.29	

^aThe lag orders (m, n) for $\sigma_t^c = \alpha + \sum_{i=1}^m \gamma_i \sigma_{t-i}^c + \sum_{j=1}^n \beta_j \left| \frac{\Delta APP_t}{\Delta OI_{t-j}} \right| + \varepsilon_t$ are determined based on AIC and SIC.

^bThe cumulative impact of Amaranth position changes is calculated as $\sum_{j=1}^n \beta_j$.

^cThe P-value from Wald test of the null hypothesis that β_j is jointly zero. Rejection of the null implies that Amaranth's relative position change leads price variability.

*significant at 5 per cent; **significant at 1 per cent.

Therefore, our conclusions further support the contention that Amaranth's activities were relatively well contained both before and after its failure.

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REFERENCES AND NOTES

- 1 United States Senate Permanent Subcommittee on Investigations Committee on Homeland Security and Governmental Affairs, Price manipulation in the Natural Gas Market and Appendix. (2007) Washington DC: Government Printing Office, http://hsgac.senate.gov/public/_files/REPORTExcessiveSpeculationintheNaturalGasMarket0.pdf, accessed 11 June 2009. Appendix – Price manipulation in the natural gas market, <http://levin.senate.gov/newsroom/supporting/2007/PSI.Amaranthappendix.062507.pdf>, accessed 11 June 2009.
- 2 Senate Committee on Homeland Security and Governmental Affairs Permanent Subcommittee on Investigations Concerning (2007) 'Excessive speculation in the natural gas market', 9 July 2007, Homeland Security and Governmental Affairs, Permanent Subcommittee on Investigations, 25 June 2007, p. 6, <http://hsgac.senate.gov/public/index.cfm?Fuseaction=Hearings.Detail&HearingID=d8a5104d-d46e-4d38-a20b-4ec5a35779a1>, accessed 12 June 2009.
- 3 Marthinsen, J.E. and Gai, Y. (2010) Did Amaranth Advisors LLC engage in interday price manipulation in the natural gas futures market? *Journal of Derivatives and Hedge Funds* 15(4): 261–273.
- 4 Bessembinder, H. and Seguin, P.J. (1993) Price volatility, trading volume and market depth: Evidence from futures markets. *The Journal of Financial and Quantitative Analysis* 28: 21–39.
- 5 Wei, S. and Kim, J. (1997) *The Big Players in the Foreign Exchange Market: Do They Trade on Information of Noise?* Cambridge, MA: National Bureau of Economic Research. NBER Working Paper 6256.
- 6 Kodres, L.E. and Pritsker, M. (1996) Directionally similar position taking and herding by large futures market participants. Risk Measurement and Systematic Risk: Proceedings of a Joint Central Bank Research Conference. Washington, DC: Federal Reserve Board of Governors, pp. 221–272.
- 7 Kodres, L.E. (1998) Effects of hedge funds on price dynamics. In: B. Eichengreen and D. Mathieson (eds.) *Hedge Funds and Financial Market Dynamics*. Washington DC: International Monetary Fund, pp. 55–61.
- 8 Weiner, R.J. (2002) Sheep in wolves clothing? Speculators and price volatility in petroleum futures. *Quarterly Review of Economics and Finance* 42: 391–400.
- 9 Irwin, S.H. and Holt, B.R. (2004) The effect of large hedge fund and CTA trading on futures market volatility. In: G.N. Gregoriou, N.K. Vassilios, L. Francois-Serge and F. Rouah (eds.) *Commodity Trading Advisors: Risk, Performance, Analysis, and Selection*. New York: Wiley, pp. 151–182.
- 10 Stewart, W.B. (1949) *An Analysis of Speculative Trading in Grain Futures*. Washington DC: U.S. Department of Agriculture. Technical Bulletin no. 1001.
- 11 Hieronymus, T.A. (1971) *Economics of Futures Trading for Commercial and Personal Profit*, 1st edn. New York: Commodity Research Bureau.
- 12 Wang, C. (2001) Investor sentiment and return predictability in agricultural futures markets. *The Journal of Futures Markets* 21: 929–952.
- 13 Sanders, D.R., Boris, K. and Manfredo, M. (2004) Hedgers, funds, and small speculators in the energy futures markets: An analysis of the CFTC's commitments of traders reports. *Energy Economics* 26: 425–445.
- 14 Hartzmark, M.L. (1991) Luck versus forecast ability: Determinants of trader performance in futures markets. *Journal of Business* 64: 49–74.
- 15 From July 2005 to January 2007, there were, on average, 208 large traders of natural gas futures contracts on NYMEX. See the testimony of Dr James Newsome, CEO New York Mercantile Exchange, Inc.³
- 16 A good example of this counterbalancing effect occurred on 29 August 2006, when Amaranth traded head-to-head with Houston-based Centaurus Energy Advisors, LLC. By day's end, Amaranth sold 16 000 contracts and Centaurus bought about 12 000. The price of natural gas futures contracts rose dramatically that day causing severe losses for Amaranth. See Marthinsen, J.E. (2009) *Risk Takers-Uses and Abuses of Financial Derivatives*, 2nd edn. Amaranth Advisors LLC: Using Natural Gas Derivatives to Bet on the Weather. Boston: Pearson Prentice-Hall, pp. 270–314.

- 17 Even if the CFTC made all its large-trader data available, there still would be significant information gaps because it would exclude unregulated transactions on over-the-counter markets and exempt commercial markets, such as ICE. Under Section 2(h) (5) (B) (iii) of the Commodity Exchange Act and CFTA Regulation 36.3(b) (3), the Commission has the authority to issue a 'special call' for information (as appropriate) from exempt commercial markets. See Lukken, W. and Dunn, M. (2007) Written Testimony of Acting Chairman Walter Lukken and Commissioner Michael Dunn Commodity Futures Trading Commission before the Permanent Subcommittee on Investigations Committee on Homeland Security and Governmental Affairs United States Senate, 9 July 2007, http://hsgac.senate.gov/public/_files/STMTCFTCLukkenandDunn.pdf, p. 16, accessed 8 August 2008.
- 18 Chatrath, A., Ramchander, S. and Song, F. (1998) Speculative activity and stock market volatility. *Journal of Economics and Business* 50: 323–337.
- 19 Nazareth, A.L. Commissioner, U.S. Securities and Exchange Commission (2007) Speech by SEC Commissioner: Remarks before the PLI Hedge Fund Conference, <http://www.sec.gov/news/speech/2007/spch060607aln.htm>, accessed 12 June 2009.