Reversing the lead, or a series of unfortunate events? NYMEX, ICE and Amaranth

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Abstract

Earlier studies on the competition for order flow have compared floor trading with automated/electronic trading systems. While most of these studies find that electronic systems lead price discovery, a few studies highlight the weaknesses of electronic trading when confronted with excessively volatile market conditions. Unusual trading events in 2006 natural gas futures trading provide an ideal setting to revisit those studies. We investigate whether hedge fund trading exploited the opacity of the electronic exchange (ICE), and whether price discovery shares reverted to floor trading (NYMEX) after the collapse of the hedge fund. We estimate daily Hasbrouck-style information shares to investigate the intertemporal dynamics in price discovery. Our empirical results strongly suggest that the information share is time-dependent and contract-dependent. Our information shares indicate that before and after the hedge fund event, ICE dominates price discovery, particularly so in the longer-maturity (relatively low volume) contracts. During the hedge fund anomaly however, NYMEX assumed price leadership, most clearly so in the final unwinding stages of the hedge fund position. The introduction by NYMEX of side-by-side trading in September does not seem to have had the desired impact of retrieving price leadership. We do, however, find that the NYMEX diurnal has "flattened" after the introduction of side-by-side trading.

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1. Introduction

Technological advances have improved the efficiency and transparency of financial markets. In particular, the introduction of electronic trading platforms in the late 1980s allowed ‘retail’ traders to actively and effectively participate in the market making process in a large range of assets. The instantaneous availability and visibility of order flow has undeniably enhanced the transparency and speed of price discovery. Trading volumes have increased, while trading costs have decreased. Surprisingly, despite their disadvantages, the traditional floor trading systems have proved to be remarkably resilient. In some cases, organized exchanges have bowed to the inevitable and adopted their own automated trading platform, but simultaneously kept their floor trading system in operation. Two major commodity exchanges, CBOT and NYMEX, run such side-by-side trading platforms.

The early 1990s were witness to fierce competition for market share among financial exchanges using different trading systems. The battle for dominance in Bund futures trading between LIFFE’s open outcry and the DTB’s Automated Trading System is a well-documented example. More recently, this competition involved online (24 hour) trading platforms competing against organized exchanges (using both floor and electronic trading systems). The organized exchanges often complain about an unfair element in this competition due to a lack of regulation of the online systems. Organized exchanges also allege that online trading platforms “free-ride” on the price discovery that occurs on the organized exchange. The online trading platforms (equity-based ECNs like Instinet, Island, Archipelago, and commodity-based ECNs like Agora-X and ICE) counter this argument by claiming enhanced transparency and therefore “cleaner” price discovery. The origin of price discovery is, in fact, difficult to establish due to the almost instantaneous arbitrage flows between the organized and ECN exchanges. Fortunately, the electronic exchange functionality has allowed researchers unfettered access to transaction frequency data, facilitating a real-time analysis of price dynamics. Ultra-high frequency order flow studies have compared floor trading with automated/electronic trading systems. The majority of these studies focused on competition between organized exchanges and found that automated trading systems lead price discovery over floor trading systems. The only exception to this finding is that floor trading is occasionally found to be more resilient in the face of high volatility, see e.g. Martens (1998). Massimb and Phelps (1994) suggest that this could be due to practical 'speed-of-execution' advantages of floor trading during fast market conditions. Madhavan's (1992) theoretical model implies large traders' preference for floor anonymity. The ability to trade large volumes with minimum price impact seems especially relevant for illiquid volatile markets.

Given their inherent volatility and relative illiquidity, it is somewhat surprising that very few price discovery studies considered commodity markets. Until the early 1970s, the organized derivatives exchanges were still the exclusive domain of commodity traders. Only after financial deregulation in the 1970s and 1980s introduced financial derivatives trading did the scene change. Financial derivatives trading volume has since grown at exponential rates while commodity derivatives trading volume started falling behind. If not venturing into financial assets, commodity exchanges attempted to grow business by introducing new asset classes, most prominent among them the energy-based assets. Early incarnations of energy derivatives have struggled to establish a foothold. Poorly designed contracts included delivery conditions open for manipulation by large traders, and a variety of other features leading to unbalanced, unattractive markets for non-hedgers. Steeply increasing (and highly volatile) energy prices; contract re-design (often motivated by ECN competition); and the entry of a new class of traders (hedge funds), has given a new lease-of-life to the energy derivatives markets in the last few years.

One of the currently more active US energy derivatives is the Henry Hub Natural Gas futures contract, against which most wholesale and retail US gas transactions are priced. This pivotal economic role is recognized federally as its trading is monitored (albeit not regulated) by the Federal Energy Regulatory Commission (FERC) for perceived distortions to wholesale prices. While volatility in natural gas futures prices is normally high (and seasonal), climatic events in recent years triggered extreme volatility conditions

– with annualized volatility peaking at 60% in 2006. Hedge funds – always on the look-out for a volatility spike – started to take interest and built significant open interest. The unusual and excessive volatility in natural gas futures prices in 2006 provides an ideal opportunity to revisit the competition for order flow studies, and in particular to assess the resilience of trading systems when things 'go wrong.' As they did in September 2006, when a single hedge fund was forced to liquidate its substantial natural gas futures/swaps positions under increasingly adverse market conditions. During the first half of 2006, the hedge fund had dominated trading in natural gas futures on NYMEX (floor) and ICE (electronic) building up spread positions in long-term maturity contracts. Around the time of the hedge fund collapse, NYMEX introduced side-by-side trading, i.e., it continued floor trading but also ran an electronic system during floor trading hours. As the NYMEX and ICE contracts are perfect substitutes, there is active and almost instantaneous arbitrage between both markets. This is particularly evident during final contract settlement when the financially settled ICE contract has to converge to the physically settled NYMEX contract closing price.

The purpose of this paper is to investigate where price discovery originates in natural gas futures/swap trading. We take special interest in the events surrounding Amaranth's trading to test whether the added volatility increased the floor information share. To avoid confounding effects, we carefully control for NYMEX' introduction of side-by-side trading systems increased its information share. Due to the extremely high speed of arbitrage we need to resort to intraday transaction data. While the electronic data are perfectly time-stamped, the floor trading data is occasionally out of order. To test for the robustness of our price discovery findings (where the sequence of prices is crucial), we therefore randomize NYMEX trade prices over very short time intervals using a simple bootstrap procedure. We filter the minute-frequency data for a pronounced intraday diurnal, and for interday GARCH volatility persistence. We fit the intraday diurnal using a Flexible Fourier Form on the number of transactions for each minute interval as a measure of "information richness." The diurnals display the typical intraday U-shape. We then estimate a Vector Error Correction model for the (filtered) futures returns, and finally compute impulse response functions and Hasbrouck-style information shares. We estimate the VECM for each day and contract individually, as well as across days and across contract maturities.

The empirical results indicate that the information share is significantly time-dependent and contract-dependent. Before and after the Amaranth events, electronic trading dominates price discovery in the nearest-maturity (high volume) contracts. During the events, NYMEX assumed spot month price leadership, most clearly so in the final unwinding stages of the hedge fund position. The introduction by NYMEX of side-by-side trading in September does not seem to have had the intended impact of reverting price leadership. We do, however, find that the NYMEX diurnal has been boosted after the introduction of side-by-side trading.

The paper is organized as follows. Section 2 gives a brief review of the natural gas futures markets, and the market events that took place in 2006. Section 3 discusses the empirical methodology and Section 4 provides the empirical results. Section 5 concludes the paper.

2. Unfortunate events: Amaranth and the natural gas derivatives markets

Natural gas derivatives are traded on organized exchanges and on electronic on-line trading platforms. The New York Mercantile Exchange (NYMEX) first started trading a standardized delivery natural gas futures contract (the *Henry Hub NG futures*) in 1990. While relative pricing (for alternative delivery hubs) is normally straightforward with commodity derivatives, the potential for natural gas supply disruptions may lead to non-trivial fluctuations in delivery location spreads. This causes 'basis' problems for hedgers, who will then prefer OTC customized contracts over a standardized delivery hub. Until its collapse in 2001, EnronOnline was the preeminent provider of OTC (principal-to-principal) energy derivatives trading. The InterContinental Exchange (ICE) was established in 2000 and, after acquiring the London-based IPE in 2001, became the second-largest energy derivatives trading platform after NYMEX. It quickly assumed the EnronOnline OTC market share in US natural gas derivatives (swaps) trading. ICE offers bilateral and cleared OTC contracts in natural gas. ICE's cleared OTC *Henry Hub NG swap* contract is virtually identical to the NYMEX *Henry Hub NG futures* contract, except that it is financially settled. In addition to a directly competing contract, ICE was also the first to offer a delivery hub "matrix" on its electronic OTC trading platform for US natural gas derivatives. Not only does this matrix accommodate hedger's preference for location-specific delivery, it also caters for very long maturities. In the face of such aggressive competition, NYMEX has also significantly expanded its product offerings. NYMEX now offers basis swaps that allow for relative delivery location pricing, it offers 60 months' maturities out to 2020, and it offers 24-hour automated (yet not online) trading on the Globex system in parallel to its floor trading during business hours.[1]

NYMEX is classified as a Designated Contract Market (DCM) under the 2000 Commodity Futures Modernization Act, and is therefore regulated by the Commodity Futures Trading Commission (CFTC) – in addition to being a so-called Self Regulatory Organization (SRO). ICE, on the other hand, is classified as an Exempt Commercial Market (ECM), operating mostly outside CFTC jurisdiction. To classify as an ECM, all transactions need to be executed on an electronic trading facility. This allows the CFTC to perform an audit trail in case of suspected market manipulation.[2] There are two crucial points of difference relevant to the purpose of our paper. First, unlike a DCM, an ECM does not have to report (large) trader positions to the CFTC, nor does it have to impose position limits. Second, an ECM does not have to make transaction prices publicly available, except to its market participants. The CFTC may, however, request ECM pricing information to be made public if the ECM serves as a significant source of price discovery. Of course, this suggests a certain anonymity advantage of trading on ICE, albeit a somewhat different type of anonymity than the anonymity provided by floor trading.

With this background in mind, we can now take a closer look at the unusual events that characterized natural gas derivatives trading throughout 2006. Late 2005, natural gas futures prices were still reeling in the aftermath of the Katrina hurricane which significantly disrupted Louisiana supply (the *Henry Hub*). Supply shortages in the fall of 2005 caused the spot month futures prices to peak in December 2005 at $15 per MMBtu (from a base of about $7 in the previous three years). At the same time, the 2006 Winter-

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[1] In 2006, daily trading volumes in NG futures/ swaps were comparable on NYMEX and ICE, although ICE volumes tended to dominate the latter months of trading in particular contracts. Distant maturity contract volumes were larger on NYMEX, see US Senate Staff Report (2007).

[2] The Amaranth hedge fund – subject of our study – was in fact pursued for alleged market manipulation of the Mar06 and May06 NG settlement prices.

Spring spread increased to $2 (from a more typical $0.50)[3]. Hedge funds took notice and increasingly participated in energy derivatives trading. One hedge fund (Amaranth), in particular, perceived the increased volatility in energy maturity spreads as an opportunity. Possibly betting on climate change, Amaranth predicted another hurricane season in the fall of 2006, causing new supply shortages in the 2007 winter months. To exploit the expected price pressure, Amaranth established long Winter '07 – short Spring '07 futures spread positions which pay off when the price disparity between March and April maturities widens.[4] While Amaranth had been trading in energy derivatives throughout 2004-5, it now did so with a vengeance. In January 2006, Amaranth accounted for about 7% of open interest in all NYMEX contract maturities for NG futures. From late February through September 2006, Amaranth's open interest share was close to 40%. Its open interest share on ICE was even close to 50%. All this combined buying and selling undoubtedly had market impact and contributed significantly to the volatility in price spreads. As in the previous year, the 2007 Winter – Spring spread increased from $1.50 in March-April to $2.50 in August, seemingly confirming Amaranth's weather bet. As Amaranth was also building spreads for the 2006 Summer maturities against the 2006/7 Winter maturities, it also caused significant price volatility in the contracts maturing during 2006. Final settlement trading, in particular, became rather hectic when Amaranth closed out or rolled-over its positions in the spot month contracts.

Amaranth expanded its NYMEX futures spread positions well beyond the position accountability levels, yet NYMEX (and the CFTC) seemed to be relaxed about this. Of course, the CFTC could not know the full extent of Amaranth's speculative positions as about one third of these positions were established on ICE. Late August 2006, a repeat hurricane season became ever less likely, and ramped-up production meant that gas supplies were forecast abundant. This triggered a collapse in Amaranth's spread position values. At first, Amaranth continued to expand its positions to counter the decreasing spread. When NYMEX finally directed Amaranth to curb its positions within prescribed position limits and accountability levels in August 2006, Amaranth simply transferred its

[3] Figure 18 in the US Senate Staff Report of the Permanent Subcommittee on Investigations (2007) neatly illustrates the significantly higher level (and curvature) of the NYMEX natural gas forward curves in late August 2005 and late August 2006.

[4] Amaranth also established substantial short positions in Aug06, Sep06 and Nov06 contracts matched with a long position in Jan07 contracts.

spread positions to ICE. It was, however, fighting a losing battle against fundamental value dictated by increasing production, as prices kept moving against its spread positions. Following increasingly large margin calls, Amaranth was no longer able to expand its positions to support price levels and needed to sell the winter maturity positions. As the natural gas futures market is naturally short, Amaranth had trouble finding buyers and once more its sales had significant price impact – but now in the wrong direction. As prices kept falling, Amaranth's margin calls became more pressing and by mid-September it needed to sell its remaining positions to its clearing firm and another hedge fund.[5] When the dust settled, Amaranth had accumulated losses of $6.5 billion. In the aftermath, the US Senate Subcommittee ordered a full investigation into the "*excessive speculation*" in natural gas markets in 2006. Subsequently, the CFTC sued Amaranth for price manipulation on two occasions in the final half hour of settlement trading in the May contract.

3. Price Discovery Methodology

Early empirical studies investigated price spillovers and contagion between 'similar' financial assets (e.g., international stock market indices, or a range of 'energy' commodities). While this literature dates back to the early 70s (e.g., Grubel and Fadner, 1971), the low frequency data available at the time limited the possible insights into price discovery. The objective of those early papers was to find evidence of contemporaneous correlation based on international diversification. Eun and Shim (1989) is one of the earlier empirical studies to use a vector autoregressive (VAR) system, which allows for intertemporal correlations between international stock market returns. The next generation of studies investigated price linkages between 'close' financial assets (e.g., the impact of derivatives trading on the value of the underlying asset). While risk-free arbitrage is now (often) possible, transaction costs may still put a brake on the speed of arbitrage. Nonetheless, cross-market price adjustments tend to occur well within a daily frequency. Kawaller et al. (1987), for example, use a VAR to investigate the minute-by-minute intertemporal price transmission between S&P500 futures and the underlying

[5] Interestingly, two other hedge funds, Centaurus and Citadel, assumed a substantial part of Amaranth's positions in a most profitable way.

index. The third generation focused on 'identical' financial assets traded simultaneously (or successively) on different exchanges or different platforms. Arbitrage is now virtually instantaneous and needs to be analysed at the highest sampling frequency. Harris et al. (2002) investigate the price relationships between cross-listed, simultaneously traded Dow equities on three US exchanges. Cross-listing arbitrage is facilitated by an intermarket trading system. Theissen (2002) investigates simultaneous floor and screen trading on a single exchange in the same security, and accordingly find almost instantaneous arbitrage. Shyy and Lee (1995) investigate the competition for order flow in Bund futures trading between LIFFE (floor) and DTB (electronic) exchanges. No intermarket trading facility here, yet arbitrage is still found to occur within minutes.

High frequency data analysis requires careful consideration of intraday market structure phenomena. Stoll and Whaley (1990), for example, correct for bid-ask bounce and infrequent trading in their high frequency stock index futures arbitrage study. One other commonly found feature in intraday returns is the typical U-shaped pattern in their volatility (and in various other market activity proxies), with high volatility at market open and close, and relatively low volatility in between. We follow Kofman and Martens (1997), who propose a Fourier Flexible Form – a low order polynomial and trigonometric function of time t (t=1,…T).

$$X_{t,d} = \sum_{k=0}^{1} X_d^k \left[\alpha_{0k} + \alpha_{1k}\left(\frac{t}{T}\right) + \alpha_{2k}\left(\frac{t}{T}\right)^2 + \sum_{i=1}^{I} \delta_{ik} D_{i,t} + \sum_{j=1}^{J}\left(\beta_{jk}\cos\left(\frac{2jt\pi}{T}\right) + \gamma_{jk}\sin\left(\frac{2jt\pi}{T}\right)\right)\right] + \varepsilon_{t,d} \tag{1}$$

where $X_{t,d}$ is the activity proxy at time t on day d, and X_d is an interactive daily activity variable on day d. A series of dummy variables D can be included to allow for special events, like the half-hour VWAP settlement period on the final day of trading.

After we estimate (1), we filter the intraday returns for diurnality

$$\Delta \tilde{P}_{t,d} = \frac{\Delta P_{t,d}}{\hat{X}_{t,d}}$$

and then estimate the following vector error correction model (VECM), see Engle and Granger (1987),

$$\Delta\tilde{P}_t = \alpha\beta'\tilde{P}_{t-1} + \sum_{p=1}^{P} A_j \Delta\tilde{P}_{t-p} + e_t \tag{2}$$

with cointegrating vector

$$\beta'\tilde{P}_t = \tilde{P}_{ICE,t} - \tilde{P}_{NYMEX,t} \quad \text{where} \quad \beta = (1 \quad -1)', \quad \Sigma = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}$$

The VECM is often rewritten in a vector moving average (VMA) specification

$$\Delta\tilde{P}_t = \Phi(L)e_t = \Phi(1)\sum_{s=1}^{t} e_s + \Phi^*(L)e_t \tag{3}$$

where $\Phi(1)e_t$ captures the long-run impact of an innovation on each of the two prices. Gonzalo and Granger (1995) propose a common factor representation for the filtered prices

$$\tilde{P}_t = f_t + T_t \tag{4}$$

with a transitory (short-term) component, T_t, and a permanent (long-term) component $f_t = \Gamma\tilde{P}_t$ where $\Gamma = (\gamma_1 \quad \gamma_2)'$. The Gonzalo and Granger parameters can be 'linked' to the VECM (VMA) parameters:

$$\Phi = \begin{pmatrix} \varphi_1 \\ \varphi_2 \end{pmatrix} = \left(\alpha_\perp' \left(I - \sum_{p=1}^{P} A_p \right) \beta_\perp \right)^{-1} \begin{pmatrix} \gamma_1 & \gamma_2 \\ \gamma_1 & \gamma_2 \end{pmatrix} \quad \text{so that} \quad \frac{\varphi_1}{\varphi_2} = \frac{\gamma_1}{\gamma_2}$$

While we are interested in long-term and short-term interactions between the two markets, we take special interest in the price discovery role performed by each market. We therefore compute the Hasbrouck (1995) information shares, IS_j. Martens (1998) and Baillie et al. (2002) show that the Hasbrouck information shares can be easily estimated from the VECM directly. Solving simultaneously for $\alpha_\perp'\alpha = 0$ and $\iota'\alpha_\perp = 1$ gives the estimated common factor weights of the variables underlying the cointegrated system, $\alpha_\perp = (\gamma_1 \quad \gamma_2)'$, so that

$$IS_j = \frac{\varphi_j^2\sigma_j^2}{\Phi\Sigma\Phi'} = \frac{\gamma_j^2\sigma_j^2}{\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2} \tag{5}$$

where the information share of a particular market is defined as the proportion of variance in the common factor f, attributable to innovations in that market. Unfortunately, the definition in (5) only holds when Σ is diagonal and price innovations are in fact often significantly correlated across markets. To eliminate contemporaneous correlation ρ between e_{ICE} and e_{NYMEX}, Hasbrouck proposes a Cholesky factorization of $\Sigma = MM'$ where

$$M = \begin{pmatrix} m_{11} & 0 \\ m_{12} & m_{22} \end{pmatrix} = \begin{pmatrix} \sigma_1 & 0 \\ \rho\sigma_2 & \sqrt{\sigma_2\left(1-\rho^2\right)} \end{pmatrix}$$

The Hasbrouck Information Shares then become

$$IS_1 = \frac{\left(\gamma_1 m_{11} + \gamma_2 m_{12}\right)^2}{\left(\gamma_1 m_{11} + \gamma_2 m_{12}\right)^2 + \left(\gamma_2 m_{22}\right)^2}, \quad IS_2 = \frac{\left(\gamma_2 m_{22}\right)^2}{\left(\gamma_1 m_{11} + \gamma_2 m_{12}\right)^2 + \left(\gamma_2 m_{12}\right)^2} \tag{6}$$

Since the ordering of the variables will change the Cholesky factorization, the information shares will no longer be unique. Instead, successive application of (6) will give upper/lower bounds on the information shares. The bounds will be tighter, the lower the contemporaneous correlation.

4. Empirical Results

NYMEX natural gas futures have been the subject of prior investigations, predominantly focused on finding optimal hedging relationships. Walls (1995) analyses optimal hedging strategies for hedgers with cash positions in twelve different hubs. Walls finds that the NYMEX futures price is in fact cointegrated with nearly all hubs' spot prices. Root and Lien (2003) refine Walls' analysis by modelling natural gas futures and (a single Henry Hub) spot price as a threshold cointegrated system. Suenaga et al. (2008) investigates the impact of seasonal and cross-sectional (across maturities) volatility dynamics on optimal hedge ratios. All these studies use low frequency data, monthly for Walls and Root and Lien, daily for Suenaga et al. This is, of course, appropriate for the practical purposes of hedgers, but is inadequate for our price discovery investigation which requires intraday data. There also studies on the cointegrating relationships between various distinct energy (futures) prices (including natural gas and crude oil), and there is a recent internal market competition study by Tse and Xiang (2005). Tse and Xiang analyse the relative price discovery role of E-mini natural gas futures and their companion regular natural gas futures. Using minute-by-minute transaction data, they find that the electronic E-mini futures contribute about 31% of price discovery. They do not investigate the intertemporal dynamics in price discovery, nor the cross-sectional dynamics – suggested by Suenaga et al. (2008) to be rather fundamental for 'seasonal' commodity futures.

The time-stamped NYMEX futures and ICE swap transaction data used in this study are obtained from the CFTC. Our sample covers all 242 trading days in 2006, for all traded monthly futures/swap contract maturities. Contract details are given in Appendix A. The first available maturity in our sample is February 2006, the longest available maturity is January 2011. While ICE provides (at least closing) prices for maturities extending to January 2011, NYMEX pricing becomes patchy beyond the April 2007 maturity. We use minute-by-minute transaction prices as a tradeoff between infrequent trading and efficiency of daily estimation. We know the number of transactions for each minute interval, the time-stamp of the last-recorded transaction in each minute interval, but we only have volume for NYMEX transactions. We filter our data for data errors and then match the two exchanges' prices when both exchanges are open. The following graphical analysis provides some information on the statistical properties. First, Figure 1 displays the daily closing prices for the spot month contracts during 2006.

INSERT FIGURE 1

In the wake of hurricane Katrina, NG futures prices were as high as \$11 per mmBtu in the winter months of 2006, before dropping to a low of \$4 per mmBtu by mid September of 2006. The annual low coincided with the demise of Amaranth. Annualized volatility for 2006 was a staggering 60% on ICE, respectively 56% on NYMEX. While not uncommon for commodity futures, these volatility levels should be considered particularly high.

Next, Figure 2 provides a snapshot of the minute-by-minute transaction prices on July 27, the last trading day in the AUG06 contract. It highlights the typical final settlement price adjustment phenomenon, where ICE swap settlement occurs against the NYMEX final settlement price. The latter is determined as the VWAP during the last half hour of floor trading. The ICE price clearly tracks the evolution of the VWAP during this settlement period.

INSERT FIGURE 2

We compute continuously compounded returns, and exclude overnight returns. Before we estimate the information discovery model, we first consider the issue of ‘importance sampling.’ Intraday transaction prices/returns are often characterized by intraday seasonality (aka diurnality) in volatility – typically a U-shape from open to close of trading. This intraday volatility pattern is correlated with, or better said, explained by U-shapes in intraday activity variables (like dollar volume, number of transactions, etc.). To weigh the intraday returns by their typical time-of-day information content, we therefore filter the raw returns by a diurnal fitted across trading days. However, rather than estimating the diurnal in price volatility, we choose to filter our returns by an estimated diurnal in activity. The activity proxy is the number of transactions in each one-minute interval. The minute-by-minute returns are then ‘weighted’ by activity in each one-minute interval allowing for some kind of importance sampling.

Averaging each one-minute interval’s number of transactions over all trading days, generates an empirical average activity diurnal as shown in Figure 3. Both NYMEX and ICE indeed exhibit the anticipated U-shaped diurnal.

INSERT FIGURE 3

The top panel displays the empirical diurnals for the spot months contracts (as they are the least noisy – average activity is highest in the spot months). While the U-shape pattern is similar, the level of activity is significantly higher at NYMEX. Also noteworthy is the delayed start – the U’s peak at 10:30 am. The second and third panels indicate the shift in activity after the introduction of NYMEX side-by-side trading in September. The middle panel considers January to July trading when the U-shaped activity on NYMEX and ICE is virtually identical. The bottom panel considers October to December trading when trading activity levels jumped on both exchanges, but significantly more so on NYMEX. We estimate the daily diurnals according to equation (1) and compute the filtered returns.[6] These are then taken as inputs in the estimation of the VECM in (2).

First, we estimate (2) across all contracts and all trading days. We find that ICE (NYMEX) contributes 34% (66%) of price discovery, on average. Next, we estimate (2) for each contract individually, but across all trading days. Finally, we estimate (2) for each contract, and each trading day, individually. The results are given in Table 1, and Figures 4 and 5, respectively.

[6] Parameter estimates for the diurnals are available from the corresponding author on request.

INSERT TABLE 1

Table 1 indicates that the error correction terms have the correct signs and are strongly significant. The short term dynamics are borderline significant for ICE, but not for NYMEX. However, the contract results indicate that the short term dynamics are occasionally significant when conditioned on the contract. It is also clear from the contract results that while NYMEX is generally more informative, this was not the case for the first two contract months.

If we condition on the trading days (by pooling all traded contracts per day), a very interesting pattern emerges in Figure 4.

INSERT FIGURE 4

NYMEX contributes around 70% to price discovery until the end of August, after which the information shares converge and towards the end of the year, ICE becomes the dominant source of price discovery. As these results include all traded contracts, we also investigate the daily information shares for the spot month contracts only. Figure 5 gives the smoothed information share estimates. Price discovery roles are distinctly different from Figure 4. ICE contributes close to 90% to price discovery until mid September, after which the information shares converge and NYMEX becomes the dominant source of price discovery. Our results for the longer maturities indicate that NYMEX contributes most to price discovery in all maturities bar the spot month.

INSERT FIGURE 5

Perhaps not surprisingly, the date on which ICE's information lead collapses coincides with the ultimate demise of Amaranth.

Since Amaranth's strategy involved a series of long-short spread positions, it is worthwhile to investigate one of these spreads in some detail. Figure 6 shows the evolution of the long MAR07 – short APR07 spread, where Amaranth was betting on a increase in winter shortages due to a new hurricane season in the fall of 2006.

INSERT FIGURE 6

There are two noteworthy features. First, the steep increases in the spread in April, June, and late July, and second the sharp drop starting in the third week of August and ultimately collapsing by mid September. These dates coincide with the events discussed in Section 2.

5. Conclusion

While floor trading is generally considered a relic of the past, a few studies have highlighted its virtues, especially in times of market stress and excessive volatility. This study investigates whether the unusual events surrounding natural gas futures trading in 2006, can shed light on the alleged resilience of floor trading in turbulent market conditions. Our results indicate that the unusual events did have a clearly discernible impact on price leadership in the natural gas market. The results also suggest the time-variation and contract-variation in information shares.

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Appendix A: Contract specifications for the Henry Hub Natural Gas Futures/Swap

	NYMEX	ICE
Trade unit	10,000 mmBtu	2,500 mmBtu
Trade price	$ per mmBtu	$ per mmBtu
Trading hours	*Floor*: 10:00 – 14:30 *Electronic*: 18:00 of prior trading day until 17:15 of trading day (GLOBEX)	*Electronic*: 14:30 of prior trading day until 14:30 of trading day
Last trading day	3 business days prior to spot month	3 business days prior to spot month
Settlement	Physical	Financial
Final settlement price	VWAP of transaction prices during last half hour *floor* trading on last trading day	NYMEX settlement price
Delivery	Henry Hub, Louisiana	NA
Position Accountability Level/Limit	12,000 net futures of any/all months, not exceeding 1,000 spot month in last 3 trading days	NA
Maximum daily price fluctuation	$3 / mmBtu Expandable after 5 minute trading halt	$3 / mmBtu Expandable after 5 minute trading halt
Minimum daily price fluctuation	$0.001 / mmBtu	$0.001 / mmBtu

Figure 1. Daily closing prices for FEB06 to JAN07 spot contracts

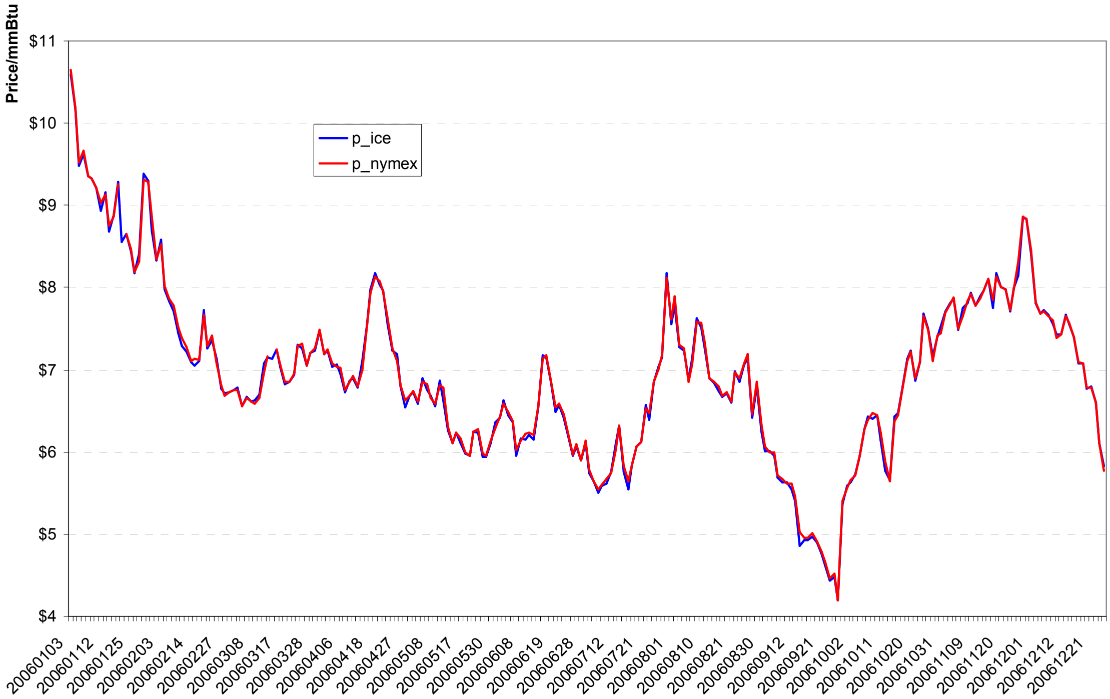


Figure 2. Final trading day AUG06 contract – July 27, 2006

Note: During the last half hour of NYMEX trading (the settlement period), the final settlement price is determined by the VWAP of NYMEX transaction prices.

Figure 3. The empirical activity diurnality

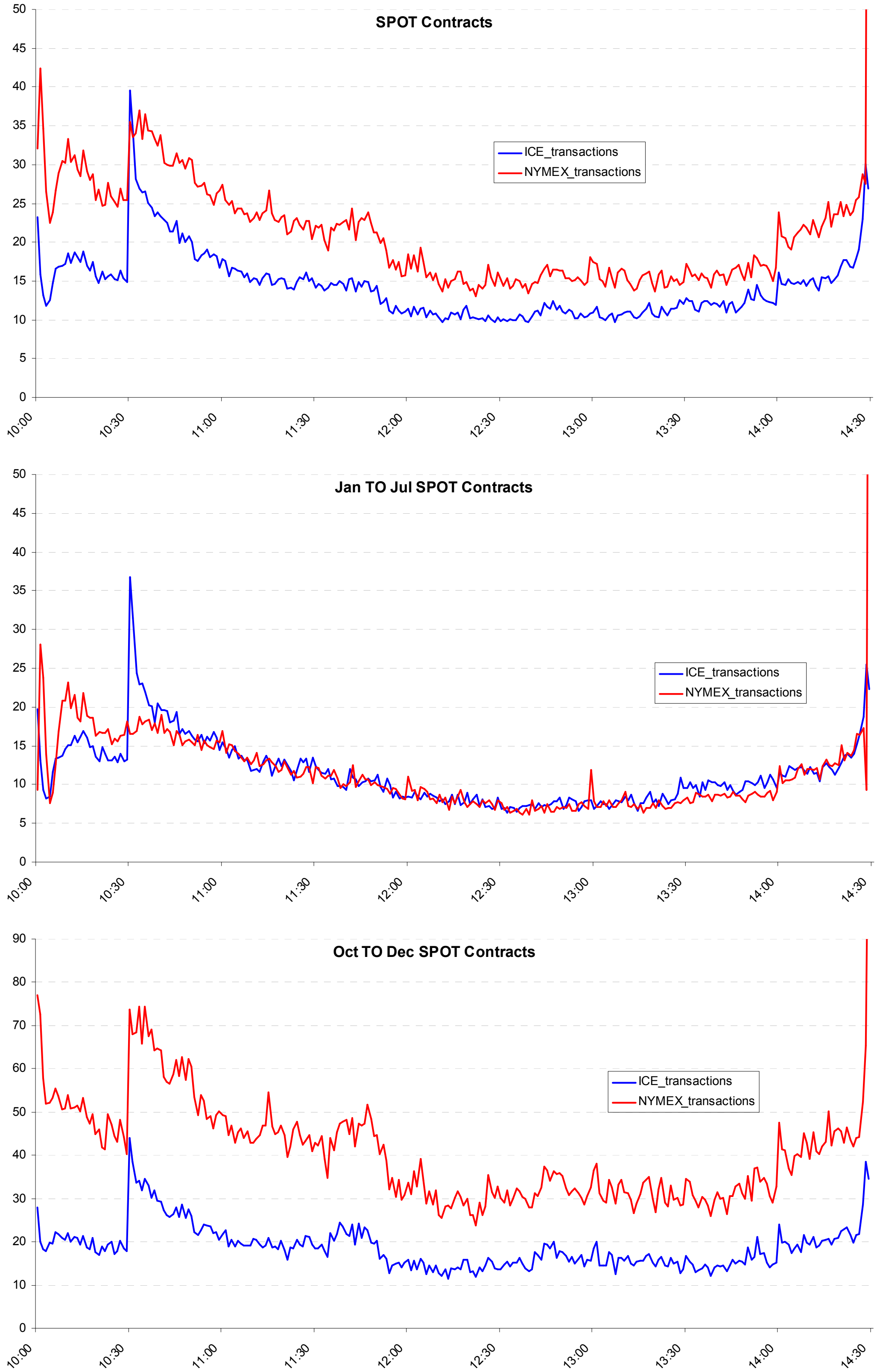
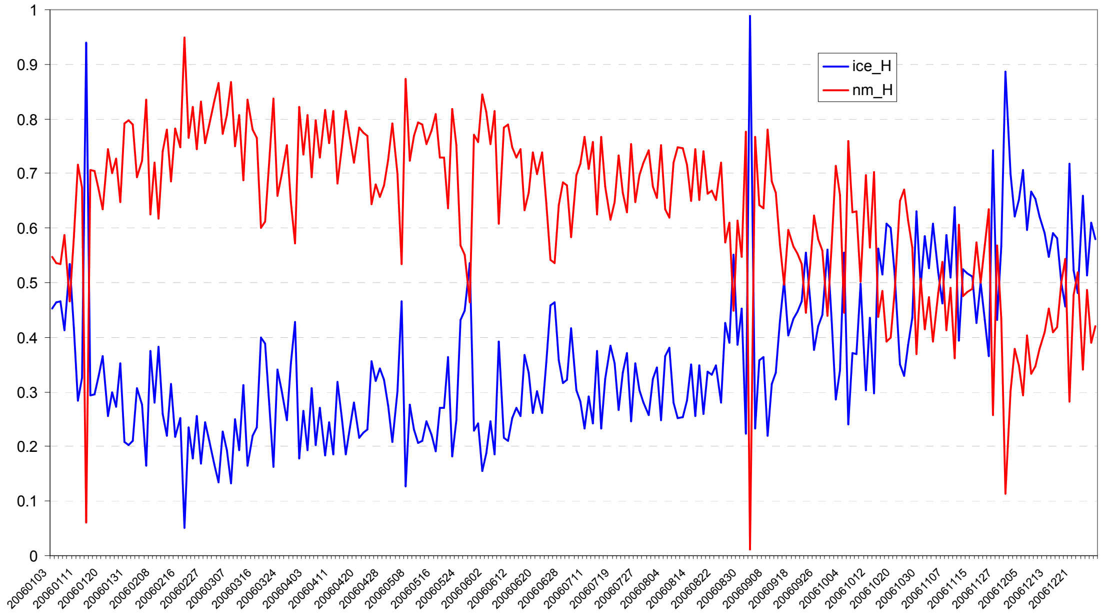
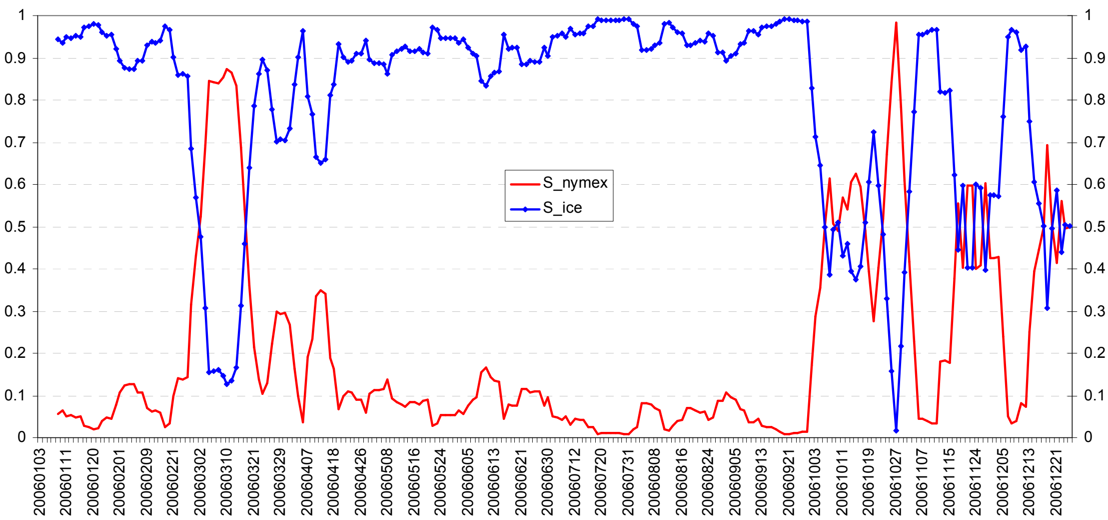


Figure 4. Daily Information Shares



Note: Information shares are computed by pooling all contracts for each trading day.

Figure 5. Smoothed Information Shares



Note: Information shares are computed for spot months contracts only.

Figure 6. The March 07 – April 07 Spread

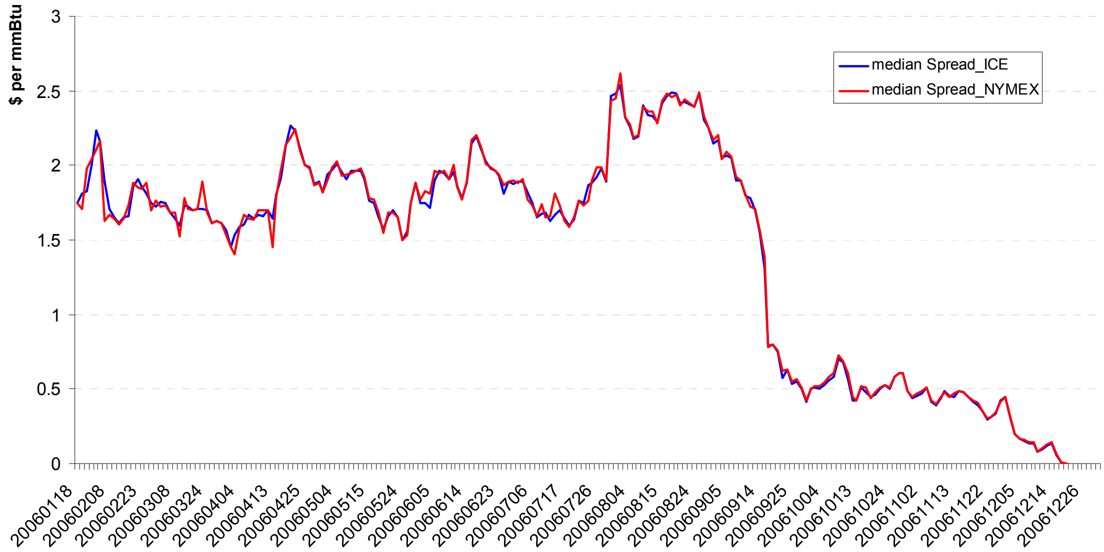


Table 1. Long-term and short-term interactions and price discovery

	Parameter Estimates and H-score					
contracts	*ice_cross*	*ice_ect*	*nymex_cross*	*nymex_ect*	*ice_H*	*nymex_H*
All	0.197	3.805	0.095	-2.276	0.34	0.66
	1.81	*7.59*	*1.39*	*-3.43*		
Feb-06	0.163	0.791	0.476	-8.624	0.99	0.01
	2.97	*0.99*	*5.72*	*-10.50*		
Mar-06	0.158	2.690	0.423	-6.182	0.88	0.12
	2.86	*4.36*	*5.39*	*-7.45*		
Apr-06	0.233	9.320	0.024	-0.924	0.18	0.82
	1.82	*14.90*	*0.84*	*-2.08*		
May-06	0.198	3.881	0.154	-3.089	0.50	0.50
	2.99	*7.08*	*2.54*	*-4.70*		
Jun-06	0.154	2.820	0.148	-3.545	0.46	0.54
	2.37	*5.59*	*2.22*	*-4.55*		
Jul-06	0.165	4.712	0.099	-2.204	0.30	0.70
	1.86	*8.24*	*1.64*	*-3.27*		
Aug-06	0.096	2.549	0.146	-2.761	0.39	0.61
	1.41	*5.49*	*2.04*	*-3.85*		
Sep-06	0.118	2.335	0.183	-3.088	0.43	0.57
	1.58	*5.09*	*2.39*	*-4.16*		
Oct-06	0.126	3.046	0.168	-3.694	0.40	0.60
	1.66	*6.75*	*2.38*	*-4.29*		
Nov-06	0.193	7.214	0.002	-0.351	0.06	0.94
	0.85	*12.91*	*0.12*	*-0.80*		
Dec-06	0.160	1.606	0.098	-3.778	0.49	0.51
	2.31	*4.39*	*1.24*	*-5.54*		
Jan-07	0.507	5.599	0.032	-1.758	0.23	0.77
	1.93	*11.39*	*0.50*	*-2.63*		
Feb-07	0.179	2.216	0.063	-2.323	0.47	0.53
	2.60	*5.12*	*1.08*	*-4.07*		
Mar-07	0.129	2.167	0.089	-1.587	0.39	0.61
	1.88	*5.44*	*1.17*	*-3.17*		
Apr-07	0.211	5.152	0.009	-0.291	0.07	0.93
	1.03	*9.56*	*0.31*	*-1.40*		
May-07	0.121	2.395	0.024	-0.923	0.29	0.71
	1.54	*5.47*	*0.48*	*-2.44*		

Note: The table gives parameter estimates and their t-values (in italics) for the error correction terms (ECT) and for the first-order short-term interaction terms (Cross). The last two columns give the mean Hasbrouck scores. The first two rows give the pooled estimates (across all contracts, the other rows give the estimates by contract.