Reconciling Theoretical Hedging Models with the Experience of Cotton Merchants in March 2008

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Abstract: Analysis of the cotton futures price spike and its effects on commercial hedgers suggest that we do not completely understand the behavior of markets and firms in periods of extreme volatility. After presenting the story of the cotton futures price spike, this paper argues that explanations related to the funding liquidity of firms and the liquidity of the markets themselves may help us better understand market volatility. A simple model of futures market equilibrium in the presence of liquidity constraints demonstrates how prices can spike as fast as they did and why such spikes can drive firms to exit.

Keywords: Futures, hedging, liquidity constraints, cotton.

Note: This is work in progress. Please do not cite without the author's permission.

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1 Introduction

In late February and early March of 2008, Intercontinental Exchange (ICE) cotton futures prices were extremely volatile. From February 29 to March 5, nearby futures prices rose the maximum allowed amount each day. When futures prices were locked limit up, trade in futures stopped but trade in options on those futures contracts continued. The volume of trade in options and options price volatility increased dramatically. Because futures prices hit limits, margin requirements on futures positions, per exchange rules, were based on synthetic futures prices derived from options values. The price changes from February 29 to March 5 resulted in unprecedented margin calls for traders who were short futures.

Cotton merchants are a marketing intermediary; they hedge using futures markets in order to reduce exposure to price risk faced when they purchase physical cotton from growers and sell this cotton to end-users. The events outlined above led many cotton merchants who used ICE futures to hedge to find that reducing price risk comes at a cost; it creates a liquidity risk because firms may not have available cash or sufficient credit to meet margin calls incurred when futures positions are marked-to-market daily. In March 2008, margin calls forced some of these liquidity-constrained firms to pay the ultimate price and exit the industry.

The events of 2008 raise serious questions about the risk management function of futures markets. This paper seeks to answer these questions by reconciling relevant economic theory with the actions of cotton merchants during this period. Though no firms have made their futures trading activity public knowledge, this paper assesses the actions of merchants using the US Bankruptcy Court records and filings of one bankrupted merchant, Paul Reinhart Incorporated, the recently released Staff Report on Cotton Futures published by the Commodity Futures Trading Commission (CFTC). The Staff Report contains information on futures and options positions held by groups of traders at a level more disaggregated and more frequent than in the Commitment of Traders Reports. Additional qualitative data was gathered from interviews with market participants.

Economists have constructed numerous models to estimate optimal hedge ratios, the proportion of firm output to be hedged. Comparisons of the optimal decisions from these models to the actions of real-world firms often indicate that firms make decisions that are inconsistent with the predictions of theory (e.g. Collins, 1997; Brorsen, 1995). For an analysis of optimal hedging to be applicable to the case of hedging cotton merchants in March 2008, it must consider constraints on firm liquidity. This is to say that it must incorporate the possibility that the firm could exhaust available credit due to margin call risk. One such recent study is Adam-Muller and Panaretou (2009). The authors analyze the optimal risk management and production decisions of liquidity-constrained firms and allow for the use of futures and options. However, their model considers only a single firm. Others have considered the liquidity constrained trader in equilibrium and have shown that the presence of liquidity constrained traders can imply a positive link between the funding illiquidity of traders and market illiquidity. Thus when traders are credit constrained, they may face high exit costs because their actions move market prices against them.

Why would markets become more illiquid? Perhaps the market viewed long orders by hedgers as a signal that fundamentals of supply and demand justified higher prices. Perhaps liquidity providers wished to squeeze hedgers. Perhaps hedgers were not motivated to pursue marginal reductions in portfolio variability, but to minimize the probability of bankruptcy over some reasonable time horizon.

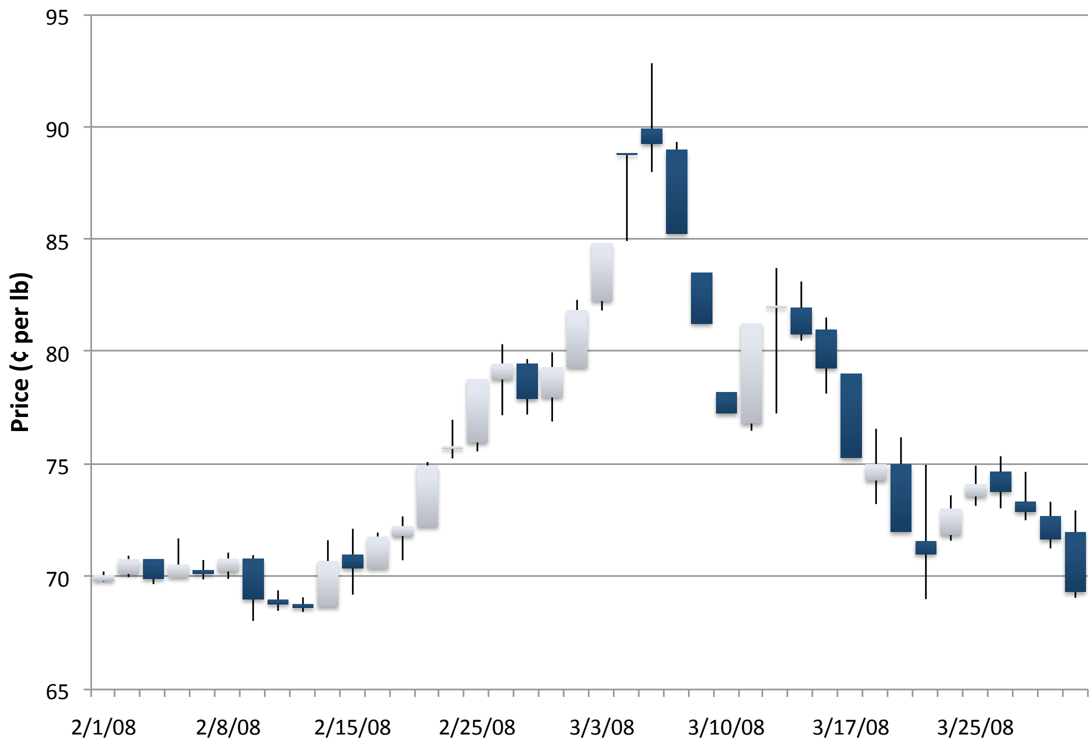
To reconcile theory with evidence, I build a multi-period theoretical model of hedging firms that captures the salient features of cotton merchants and of cotton markets in periods of extreme volatility. In the initial period, the model considers merchant firms that have hedged forward contracts with growers by taking a corresponding short futures position. The choice variables for this firm are suggested by the CFTC Staff Report (CFTC, 2010) which noted that when credit was constrained, hedgers had three options: close out positions, balance short futures positions with synthetic long positions taken in the options market, or obtain sufficient financing to sustain their short positions. These choices were further constrained by daily price limits that stopped trade in futures. Note that these options were not mutually exclusive and that they ignore the possibility that firms had access to over-the-counter derivatives such as swaps contracts that are not disclosed to the CFTC. The simplified model presented here ignores trade in options on futures to focus on the relationship between funding liquidity and market liquidity.

2 Case Study

The motivation for the theoretical work in this paper is driven by the events that occurred in the cotton futures market in March 2008[1]. The facts presented in this section suggest that the price spike that occurred in the futures market at this time was not driven by supply and demand fundamentals. It also suggests that commercial hedgers who used the future market to manage risk were unprepared for and suffered negative outcomes due to this price movement.

[1]Popular media accounts of these events can be found in Davis, Ann. "In Mystery Cotton-Price Spike, Traders Hit By Swirling Forces." *Wall Street Journal*, p. A1, August 13, 2008. and Meyer, Gregory. "Cotton Price Rally But A Mood of Caution Still Prevails." *Financial Times*, January 5, 2010.

Figure 1: ICE May 2008 Contract Cotton Futures Prices, February-March 2008.



Note: Light bars indicate upward price moves, dark bars indicate downward price moves, and vertical lines represent the trading range for the day.
Source: Commodity Research Bureau

Cotton futures prices began to move higher in late-2007, concurrent with a general commodity price boom. Bullish sentiment for cotton prices was partly driven by the view that high prices for other commodities would draw acres towards these crops and away from cotton. However, very high inventory levels, both in the US and elsewhere, should have moderated prices. Stocks-to-use ratios in the US were above 50%, a 25 year high. (USDA PSD Online) Cash prices in the United States remained far below nearby futures. Basis levels in Memphis, Tennessee (a futures delivery point), normally in the range of four to six cents under the nearby futures price, were 25 cents under nearby futures.

A time series of nearby cotton futures prices is shown in Figure 1. At the end of trading on February 29, 2008, May cotton futures closed near contract highs at 81.86 cents/lb. On the next trading day, March 3, cotton prices spiked, hitting limit amounts that stopped trading for the day[2]. Trade in options on these futures contracts continued and observed market volatility increased the risk premium priced into options values. On March 4 and

[2]Limits on daily price movements on ICE cotton futures were three cents above or below the previous day's closing price when prices were below 84 cents/lb and four cents when above 84 cents/lb. The CFTC (2010) notes that these limits were tighter as a percent of contract value than for other agricultural commodities.

5, prices spiked again, with May futures reaching 92.86 cents/lb mid-morning on March 5. It is believed that the continued increase was driven in part by commercial hedgers buying futures to unwind the short positions on which they had incurred large losses the previous day.

Futures trading is highly leveraged because traders post margin typically equal to 5-10% of the futures contract value. At the end of each trading day, futures positions are marked-to-market. If prices have moved against the trader, more margin money must be posted. Unique to this case, the amount of margin money required in ICE cotton was based on volatility implied by options prices. Continued trade in options after position limits were hit meant that cotton merchants faced unprecedented margin calls. For example, on March 4, margin calls for traders who were short futures were 12.04 cents/lb, equal to three or four times daily price limits CFTC (2010). Short traders in the cotton futures market were required to meet $1 billion in margin calls in a single day (O'Neill, 2010).

Adding to the uncertainty was the elimination of floor trading for cotton futures; March 3, 2008 was the first day that ICE cotton trading was completely electronic. Anecdotal evidence suggests that commercial firms were reliant on information relayed by floor traders and this was lost with the move to full electronic trading. After the spike, futures prices fell quickly to approximately 70 cents/lb. Subsequently, futures prices declined further, falling below 40 cents/lb in early November 2008.

In response to these events, the CFTC, the regulatory agency responsible for futures market oversight, conducted an investigation to determine if futures market were deliberately manipulated. This investigation studied the futures and options market positions taken by commercial and speculative traders. It found that the largest net long traders, whose positions were mostly speculative and who stood to gain the most from an upward price move, were "inactive" during critical periods of price movement in late February and early March 2008. Net short commercial hedgers, namely cotton merchants, were the most active, along with traders who held small positions and traders whose trading patterns were indicative of scalping. This evidence suggests that an economic theory that explains the price spike event should be driven by the actions of net short commercial hedgers.

The price spike had significant, negative, and unexpected consequences for cotton merchants. Losses due to margin calls on futures positions caused substantial financial losses and forced a number of firms to exit the industry. In particular, a group of merchants who were family-owned and dealt almost exclusively in cotton either sought to be acquired, wound up operations, or declared bankruptcy. The largest of these firms were Dunavant, Paul Reinhart, and Weil Brothers. All of these firms were among the largest cotton handlers in the United States and all had significant operations worldwide (Meyer, 2010).

Firms in the cotton business are generally closely held and little is known about the specifics of their operation. However, the availability of publicly available bankruptcy proceedings for one exiting firm, Paul Reinhart Inc., the US subsidiary of Swiss firm Paul Reinhart AG, provide unique insight. Reinhart filed for bankruptcy protection on October 15, 2008. Like other merchants, Reinhart entered into forward contracts with growers in late 2007 and early 2008, hedging those purchases by selling futures. The run up in futures prices meant that Reinhart was faced with about $100 million in margin calls. (The firm had annual revenues of approximately $640 million in the fiscal year prior to the spike.) On March 4, Reinhart closed their futures positions and entered into "various options trades" to try to maintain hedges in an effort to reduce margin risk and free up liquidity. But Reinhart incurred further losses on these trades, causing it to default on its loans. Reinhart signed an agreement with its lenders that would allow it to reestablish its hedges for the forward contracts it still held with growers. In this agreement, the lenders gained the right to sweep cash from Reinharts accounts when account balances were above given thresholds and the right to veto the sale of Reinhart to third parties.

Reinhart began to seek bids for its operations. In July 2008, it obtained a bid from Allenberg Cotton that would ensure performance on its existing forward contracts, but the lenders vetoed this bid. In the meantime, cotton prices fell and Reinhart made significant gains on the short futures positions it established following its restructured lending arrangement. Reinhart states in filed bankruptcy papers that its lenders swept $180 million of these gains from its brokerage accounts. After being forced by its lenders to liquidate most of its futures positions in early October 2008, Reinhart filed for bankruptcy.

The Reinhart bankruptcy case provides evidence of how credit constraints can play out for real-world firms. Often economists think of financial constraints as hard limits that bind the operations of a firm. In the case of Reinhart, the firm was enabled by its creditors to nominally continue operations, but its existence was as a ward of its lenders. The case also raises a number of interesting questions: Why did prices move so high, so quickly? Why did some firms have the liquidity to survive unprecedented margin calls when others did not? How does information flow in and out of markets and how does this affect the decision making of traders? The literature review and model sections below begin to address these questions.

3 Literature Review

In an effort to understand the dramatic effects of limited credit availability as played out in the case above, theoretical models of hedging behavior have incorporated agents who face liquidity constraints while using futures to hedge. One class of model considers the actions of a single firm facing price and liquidity risk. In the absence of liquidity risk, simple models of the risk-averse hedging firm (e.g. Holthausen, 1979) suggest that it is optimal for the firm to fully hedge, that is to take a position in the futures market that fully offsets its cash market position. There has been considerable effort in the economics literature to explain why the optimizing firm might not fully hedge; explanations related to the funding liquidity of the firm are part of this literature. The basic result of these papers is this: the presence of liquidity risk implies lower hedge ratios.

3.1 Firm-level Optimization

A recent paper by Adam-Muller and Panaretou (2009) is characteristic of this literature and describes with relative acuity the problem facing short hedgers observed in the cotton futures market. It is constructive to consider the detailed optimization problem presented in this paper in order to develop a more generalized model later. Adam-Muller and Panaretou (2009) consider a two-period model of the firm making production decisions and futures and options trading decisions. The firm maximizes its utility over expected final-period wealth in each period, responding to futures price movements that follow an exogenously specified random walk. There is a terminal period following the firm's final trading decision in which the cash and futures positions are closed and final wealth is realized. Unlike many previous studies that represent the liquidity constraint as an inability to meet cash flow obligations beyond a given threshold (e.g. Lien, 2003), the firm must cover cash flow shortfalls (due to margin calls on futures positions, for example) by borrowing at an exogenously determined rate above the risk-free rate.

The main result of the single-firm optimization problem considered by Adam-Muller and Panaretou (2009) plays out over each of the two periods. Initially, the firm will less than fully hedge to reduce its exposure to liquidity risk, that is the risk of a margin call on its position prior to futures expiry. If the market moves against the hedging firm after the first trading period, the firm must reduce its futures position further. These results are important in understanding the potential actions of individual agents, but by construction cannot explain market-level phenomena such the dramatic price movements and exit of some firms observed during the cotton futures price spike in 2008. The case study above suggests that it was not action, but the interaction of firms in the market that lead to the liquidity shortfall event.

3.2 A Market in Equilibrium

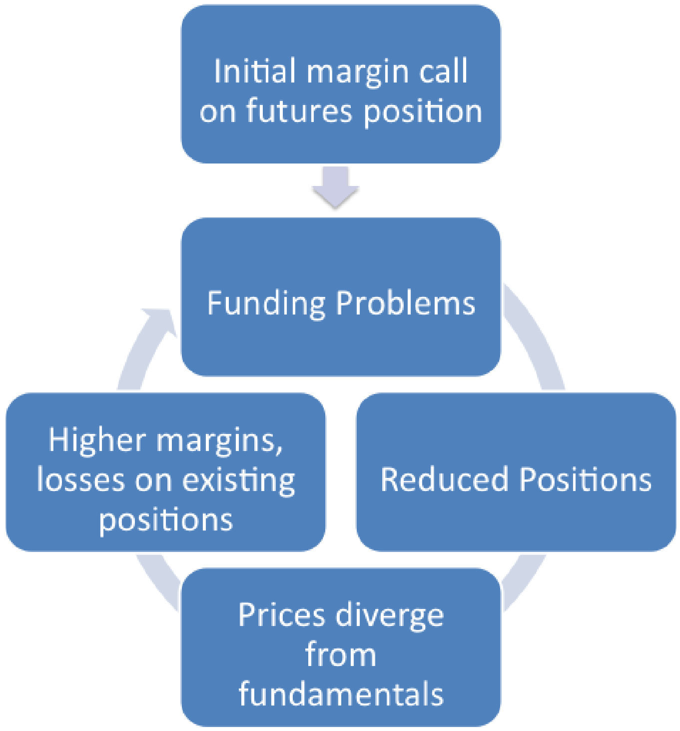
An equilibrium model of futures trading is necessary to explain market-level phenomena. The financial economics literature contains a number of works that consider firm liquidity in the context of dramatic market events. Three major economic events, the "Black Monday" crash of 1987, the collapse of Long Term Capital Management in 1998, and the recent financial crisis induced by the "subprime" mortgage collapse, seem to have inspired this work. This work points to a more complicated type of liquidity risk. Whereas the single-firm model above considered liquidity risk as an increased cost of borrowing, these papers suggest that when markets are volatile enough to make access to credit an issue, liquidity risk is more complicated. The liquidity risk faced by firms is related not only to borrowing costs but to the threat that when unmet margin calls forces the closing of futures positions, the firms will face illiquid markets. The firms cannot close their positions without incurring further losses as market prices move against them.

Liquidity events create a positive feedback cycle between liquidity and loss events for firms who face liquidity risk in the markets where they manage price risk. Brunnermeier and Pedersen (2009) present a visualization of this process as what they call a "liquidity-loss cycle." This cycle is presented in Figure 2, adapted to reflect the cotton futures market story. The cycle indicates how market conditions are fragile; one event can trigger a sequence of negative outcomes that feedback into further negative outcomes. While Brunnermeier and Pedersen (2009) is the most recent work to examine the phenomenon of funding liquidity and market liquidity, previous work that considered liquidity constrained traders such as Chowdhry and Nanda (1998) and Liu and Longstaff (2004) explore similar circumstances in which funding liquidity implies some degree of market "fragility".

Brunnermeier and Pedersen (2009) develop a theoretical multi-period model of asset trading that generates this fragility in market prices and funding conditions. This model is based on a model of market liquidity developed in response to the 1987 stock market crash by Grossman and Miller (1988). The model considers three types of agents familiar also in the cotton case: customers, speculators, and financiers. Financiers provide credit to the speculators, who act as market makers or liquidity providers to customers who wish to trade risky assets. In the models of Grossman and Miller (1988) and Brunnermeier and Pedersen (2009), it is speculators who face liquidity constraints. Asset price fundamentals follow an exogenously specified time-series process. Each type of agent solves its own optimization problem at each period.

There are two important measures in the model of Brunnermeier and Pedersen (2009). First, the funding liquidity of speculators is defined by the shadow cost of capital. If the liquidity constraint binds, that is speculators have enough liquidity to meet the margin

Figure 2: Visualization of the “liquidity-loss spiral”



Source: Adapted from Brunnermeier and Pedersen (2009)

requirements on the asset positions they find to be optimal, then the shadow cost of capital is positive. Note that margin requirements in this case refer to the capital requirements that financiers place upon borrowers. Second, market liquidity is measured as the absolute value of the deviation of market prices from their fundamental value. Brunnermeier and Pedersen (2009) shows analytically that these two measures are linked. This is due to the fact that speculators who are well informed about the fundamental value of an asset see deviations from fundamentals as an opportunity for profit when prices and fundamentals eventually converge.

The nature of the link between market liquidity and funding liquidity is the key result from the paper of Brunnermeier and Pedersen (2009). The way in which margins are set drives this result. When financiers know the fundamental value of the asset and know that market prices and fundamentals must converge in the terminal period, margins can be set in a manner that promotes trades to bring prices in line with fundamentals. Brunnermeier and Pedersen (2009) refer to this case as one of stabilizing margins. When margins are set without knowledge of fundamental values, their model shows that margins can be destabilizing. Financiers could set margins assuming that price volatility is indicative of fundamental volatility. Since funding liquidity risk for traders is higher when volatile is greater, illiquid markets (where price moves away from its fundamental value) could result in higher margin requirements. This produces the positive feedback displayed in the liquidity-loss spiral seen above. Thus, Brunnermeier and Pedersen (2009) show that funding liquidity constraints can make markets fragile. Small changes in fundamentals can lead to large jumps in illiquidity in both markets and funding conditions.

The theoretical literature that generates these results can be useful in developing a model to explain why prices moved so dramatically in the cotton futures market in 2008 and why firms were forced to exit as a result. However, in attempting to adapt these models to the case of liquidity constrained hedgers, a number of complications arise. Unlike the models of Brunnermeier and Pedersen (2009) it is not speculators or market liquidity providers who are funding constrained. If the funding constrained traders are short hedgers, then a loss-inducing price move in the futures market is one where prices move above fundamental values. It is difficult to generate such a move theoretically. Speculators who know the fundamental value of the asset and who know that convergence must occur in the terminal period are unlikely to allow this. Moreover, if any level of risk aversion is posited for hedgers, the implied risk premium in futures prices means that prevailing prices should be lower than fundamentals.

4 A Simple Model

I propose a simple model of hedging behavior that demonstrates how funding constraints might make markets illiquid and drive prices to exceed fundamentals. This simple model is an adaption of ideas presented in Bernardo and Welch (2004) and Pedersen (2009). One way of generating price spikes and liquidity spirals is to model these events as a "running for the exit" phenomenon. The economic study of this phenomenon owes a great deal to the seminal paper of Diamond and Dybvig (1983) that modelled runs on banks and showed that banks with long maturity assets and short maturity liabilities may be unstable. Similar ideas can describe runs in asset markets. My model considers the case of futures hedgers explicitly, where firms hold longer term physical positions and face liquidity risk due to margin calls in the short term.

Suppose there are two hedgers, A and B, holding short futures positions, $x^A = x^B$ corresponding to offsetting positions in the physical market. Short futures positions are represented by negative values such that the combined initial position is $x_0 = x^A + x^B \leq 0$. The firms are identical except that they vary in their ability to finance margin calls. Since hedgers in this case are net short, someone else must be net long. Suppose that the long side of the futures positions x^A and x^B are held by a sector of market makers or liquidity providers. Following Bernardo and Welch (2004), this group is comprised of all traders willing to trade with hedgers on demand without fear of liquidity shocks. Suppose this group gives rise to an aggregate "supply of futures positions" function with a slope of one. That is, if a hedgers wishes to buy one contract, the price must rise one unit and if a hedger wishes to sell one contract the price must fall one unit. The inherent assumption is that liquidity provision is undertaken by risk averse agents and cannot be expanded, which is why buying or selling pressure causes prices to rise or fall.

Hedgers may trade in each of two periods, $t = 1$ and $t = 2$. In each period, the orders for trades placed by hedgers are executed. As in Bernardo and Welch (2004), we assume that execution order is not sequential. No trader can gain an advantage by "front-running" their orders and no trader is discouraged from trading because they expect to be placed in the rear of the selling order. Instead, all traders receive the average execution price of all orders submitted in that time period. Bernardo and Welch (2004) note that the assumption that markets lack perfectly sequential execution may be realistic in the case when markets are closed, as in the cotton case when the market was locked limit up. This explanation is helpful, although this assumption is made for tractability as much as to reflect reality.

Since the firms are fully hedged, in the absence of exogenous shocks they do not trade. Suppose instead that the firms face an exogenous shock to futures market prices in the initial period, $t = 0$ and the shock is positive so that the prevailing price after the shock, p_0 is above the price at which the firms acquired their positions in the futures market. Suppose too that this implies a margin call that exhausts the available credit of A, but not B.

Consider two possible scenarios. In the first scenario, B does not know about A's distress and so has no reason to trade at $t = 1$. A liquidates his position and the futures market price moves along the supply of futures positions curve to p_1. The average execution price price for the trades of A is the midpoint between p_1 and p_0, or $(p_1 - p_0)/2$. Obviously, A is worse off, because he has taken a loss on his futures trades and is unhedged. However, B is also adversely affected, taking a mark-to-market loss of $p_1 - p_0$ on her short position. With A out of the market, B has no incentive to trade in period 2.

In the second scenario, B knows that A is distressed after period 0. B can act on this information to make herself better off than in the first scenario. B takes A's distress as a signal about how market prices must move in the coming trading period, $t = 1$. Knowing A must exit, B buys back her short futures position in period 1; both hedgers fully exit the futures market at $t = 1$ so that their combined position is $x_1 = 0$. This moves the market price to p_1^*. Since neither hedger has any advantage in having their order filled, the average execution price for both A and B is again the midpoint between p_0 and p_1^*. In this simple two-trader case with equal starting positions, the midpoint is p_1, the prevailing price in the first scenario. After A has exited, B can reestablish her hedge in period 2 at an average execution price, p_2^*, that is the midpoint between p_1 and p_1^*. Having bought at a price below what she later sold at, B is better off by an amount equal to $(p_2^* - p_1*)x^B$. B is again fully hedged in anticipation of future shocks.

A visual representation of each scenario is presented in Figures 3 and 4. The buy and sell orders placed by A and B can be represented as movements along the supply of speculation curve, the upward sloping line in each panel. The left panel shows the price change from p_0 to p_1 that results from A's exit. The corresponding net short futures position of all hedgers moves from x_0 to $x_1 = x^B$. The right panel shows the first period move from p_0 to p_1^* and the second period move back to $p_2^* = p_1$.

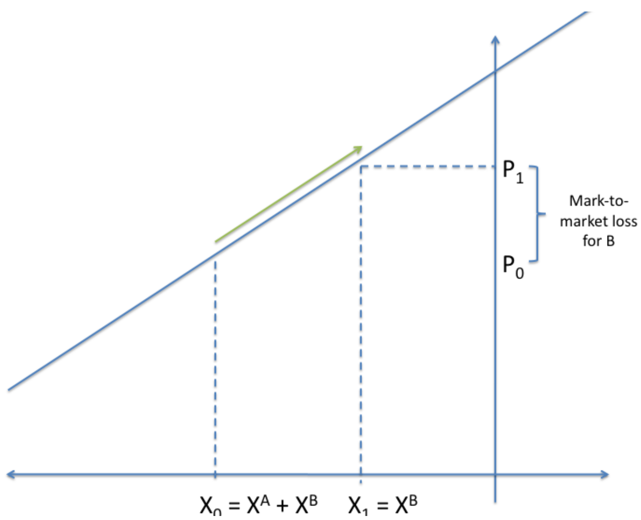


Figure 3: Equilibrium in Scenario 1

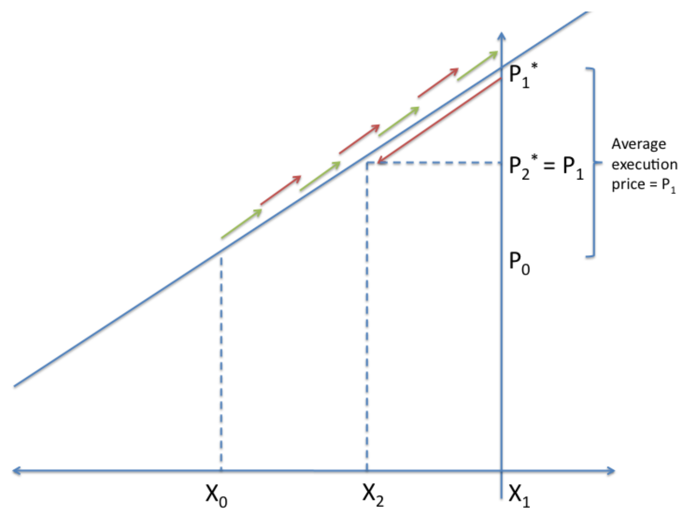


Figure 4: Equilibrium in Scenario 2

This model demonstrates how the funding illiquidity of one trader can lead to market illiquidity. When the distressed hedger is forced to exit, he finds that he receives poor order execution because other traders are running for the exit. The market is illiquid when liquidity is needed most, because the ability of market makers to provide liquidity is fixed and the run for the exit creates greater demand for market liquidity.

The outcome of the second scenario demonstrates in a very simple way how the liquidity spiral described earlier may begin. If a third hedger, C, is added to this model, one can see how the spiral might be sustained. If the funding liquidity constraint of C is less restrictive than that of B and if both hedgers run for the exit, B may face a liquidity event and be forced to exit the futures market. Note

In general terms, the story told by this simple model is consistent with the cotton case in three important ways. First, the time-series of market prices generated by this model is broadly consistent with the price spike observed in the cotton market. Prices moved up rapidly, declined as just as quickly, then leveled off above the level where they began the run. Second, the model does not rely on the actions of speculators to move prices. As the CFTC noted, traders with large long speculative positions were not making trades that moved market prices; it was the actions of short hedgers that was concurrent with large price moves. Third, it allows, albeit only by construction, for some hedgers to be forced to exit while others are not. It can be postulated that in the cotton case, the major reason some firms survived was their ability to access liquidity quickly. For multi-commodity merchant firms such Allenberg (Louis Dreyfus) and Cargill, cotton is a small part of their business. Such multi-commodity firms may be able to "self-insure" against margin call risk when smaller merchants cannot.

5 Discussion and Conclusion

The model presented in this paper is a first step towards reconciling theoretical modeling of hedger behavior with real world events like those that occurred during the cotton futures price spike in 2008. However, the simple model of trading and exit poses a number of questions that should be addressed in future research. Whereas the simple model considered mechanistically the ability of one trader to react to the action of others, a complete model would consider the optimization problem of all agents, as was the case in Brunnermeier and Pedersen (2009). Considering the results and omissions from the simple model can inform the construction of a more complete model.

Further analysis should consider the following questions. Most importantly, what motivates commercial firms to hedge and what motivates speculators to provide liquidity? Hedger risk aversion is a common assumption. In the model presented above, risk aversion and the provision of a risk premium in futures prices also motivate speculators to take the opposite side of the trades desired by commercial hedgers. There is considerable debate in the literature about the presence of a risk premium and assuming its existence should not be done without good reason. Assuming that traders are risk neutral and still unconstrained in size of the positions they may take on is also problematic. The model must contain some mechanism by which price movements occur and it is very difficult to generate price movement when liquidity provision is unlimited at a price equal to the speculators long-run expected price level.

This paper does not explicitly address the relationship between supply and demand fundamentals in the cash market and the futures market price. Clearly in the case of cotton, prices during the spike exceeded fundamentally justified levels. But how can a model with rational, profit maximizing speculators generate prices that exceed fundamentals? Speculators would not enter into trades with negative expected profits, unless their expectations are subject to error in some way. It could be the case that speculators do have less information about fundamental prices and acting upon flawed information can cause temporary deviations from fundamentals. It might also be the case that speculators do not act uniformly, so that some subset of speculators are willing to trade no matter what the prevailing price.

One more matter that must be resolved is the motivation for lenders to force the exit of hedging firms from the future market. Losses incurred by firms because they could not ride out the spike implied potential losses for lenders if firms could not repay their existing loans. Even though the cash market prices did not move in concert with futures, major hedging firm should have been able to engage in arbitrage using the physical cotton that they held, so long as they did not close their short futures positions. The lenders could have enabled this arbitrage or done it themselves, but something stopped this from happening. There is a literature in finance on the limits to arbitrage that may help explain what happened.

Finally, a complete model would describe the mechanism that ends the spike or stops the run in prices. In the model in this paper, the run stops because there is only one hedging firm left in the market. Clearly, requiring the exit of all the firms save one is an unrealistic assumption. This is where a more complete definition and proof of the existence of market equilibrium is necessary.

Answers to these questions will have important public policy implications. The commodity price boom and bust, including events in the cotton market, have spurred calls for derivatives regulation, including calls for controls on price movement and trader positions. Additional work can enable analysis of such policies that is robust to the types of events observed during the commodity price spike.

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