THE EFFECTS OF DAILY PRICE LIMITS ON COTTON FUTURES AND OPTIONS TRADING

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Federal Reserve Bank of New York
Research Paper No. 9627

August 1996

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Current version: August 15, 1996

Abstract

The New York Cotton Exchange (NYCE) imposes price limits on the trading of cotton futures, whereby the price at which cotton futures trade during a day is restricted to a band centered around the previous day's close. However, the NYCE has no such restrictions on the trading of options on cotton futures. These exchange rules allow for essentially a controlled experiment to study the market participants' responses to the price limits on futures. We show that, as a higher fraction of the trading day is constrained by the price limit, futures volume significantly decreases, options volume significantly increases, but the average aggregate volume of cotton trade remains unchanged. The empirical analysis indicates that market participants react rationally to the price limit in the futures market by transferring their trading activity to a market without price limits.

* Federal Reserve Bank of New York, Capital Markets Function, Research and Market Analysis Group. The opinions expressed in this paper are those of the authors and do not necessarily represent those of the Federal Reserve Bank of New York or the Federal Reserve System. The authors would like to acknowledge the valuable research assistance of Elizabeth Reynolds and Erika Nanke. All comments are welcomed and appreciated.

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INTRODUCTION

Trading limits refer to exchange-mandated restrictions on trading during times of market stress. They normally go into effect during times of extreme price volatility, unusually high trading volume, or massive one-sided order flow. Such mechanisms, including price limits, trading halts, circuit breakers, and position limits, have been in existence in many commodity and financial markets for years.[1] Various arguments have been advanced concerning their effectiveness, and although the subject has received a great deal of scrutiny following the stock market crash of 1987, no consensus has emerged regarding their ultimate usefulness. Many of the theoretical arguments both for and against trading limits remain controversial, and much of the empirical evidence is inconclusive.

Opponents of trading limits argue that unfettered trading in the asset markets is more efficient than regulated trading. Some of the more frequently cited disadvantages of trading limits are that they prohibit potentially mutually beneficial trades that would occur voluntarily, that they impose costs by preventing market participants from liquidating existing positions or establishing new hedging positions, and that they create intermarket distortions by disrupting spot and futures price co-movements (CFTC Report, 1988; Chance, 1994). In addition, it has been argued that the imposition of trading limits often impedes the price discovery process by upsetting the normal flow of information (Lee, Ready and Seguin, 1994), and by creating what many market participants call the "magnet effect" (Hieronymus, 1971; Cantor, 1989; Fama,

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[1] Although different authors use terms in different ways, this paper uses the following terminology to catagorize trading limits: *price limits* create a band within which the price of an asset can trade; *trading halts* prohibit trading of an asset during a time period in which it normally trades; *circuit breakers* prohibit the simultaneous trading of an asset and a derivative security (such as futures or options) on the asset; and *position limits* control the net amount of an asset that any one market participant can hold.

1989). This "magnet effect" potentially leads to increased trading volume and price variability as large institutions, which would otherwise have the flexibility to choose the time periods and/or market environments in which to trade, feel compelled to suboptimally advance the execution of trades (Subrahmanyam, 1994).

Proponents of trading limits base their support on the notion that there is a "public good" in maintaining an orderly market, and that individual traders do not take this externality into account when trading. For example, trading limits can discourage unreasonable prices that result from "excessive speculation" (Khoury and Jones, 1983), since they provide a cooling-off period that gives traders time to absorb new information (Ma, Rao and Sears, 1989). It is believed that trading limits can serve as a partial substitute for margin requirements (Brennan, 1986),[2] may lessen credit risks or a loss of confidence in the marketplace, and may curtail detrimental trading strategies by formalizing the economic reality that markets have a limited capacity to absorb enormous one-sided volume (Brady Commission, 1988).[3]

This paper takes a unique approach in addressing the effectiveness of price limits.[4] Using data on cotton futures and options on futures at the New York Cotton Exchange (NYCE) during 1995, we study the market's response to the imposition of the price limits with respect to shifts and/or changes in trading volume and strategies. The cotton futures and options market

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[2] Brennan (1986) shows that price limits may serve as a partial substitute for margin requirements in ensuring contract performance, and that it may be optimal to run some risk of a trading interruption in order to reduce margin requirements (unless there is costless arbitrage between the cash and futures markets).

[3] The Brady Commission (1988) suggests that circuit breakers protect both the markets and investors by potentially reducing the likelihood that flawed trading strategies (described as huge transactions in one direction within a short time period) would be pursued to the point of disrupting the markets or threatening the financial system.

[4] It is important to distinguish between price limits (typically imposed on regulated futures exchanges) and trading halts (typically imposed on stock exchanges) since, under price limits, trading can continue at or between the upper and lower limits, while trading halts stop trading, regardless of price, for some period of time (Kodres and O'Brien, 1994).

provides an interesting opportunity to address questions relating to price limits, since it is a market where futures trading is subject to limits while options on futures trading is not.[5] We examine whether or not there is an obvious substitution effect by testing if the volume in related contracts (various options contracts and futures of different tenors) that are not in limit increases when one or more futures contracts go into limit. We also examine the volume of various types of options strategies (synthetic futures, deep-in-the-money options, or option spreads) that could conceivably increase as a result of price limits.

The results of our analysis suggest that, on average, the total "price risk traded" on the NYCE remains essentially the same on days when one or more futures contracts are in limit compared to days when the limits are not binding.[6] The composition of trading does change, however, as there appears to be a seamless transition of trading from futures contracts to options-based trading strategies.

The paper proceeds as follows. Section I provides background information for the cotton market, including the spot market, the futures market, the options market, and the "spreads" market. Section II describes the data that are used in the empirical analysis. Section III tests for competitiveness and efficiency in the cotton futures and options markets by examining the concentration of trading and testing for arbitrage opportunities. In Section IV, we present univariate regressions of trading volume and the fraction of the day that the futures are in limit. In Section V, we present multiple regressions of trading volume and other possible explanatory variables. Finally, Section VI provides a summary and conclusions as well as a discussion of

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[5] It is not uncommon to have price limits on the futures contracts and not the options contracts, a situation found in many agricultural, metal and energy futures markets in the U.S. Most financial futures exchanges, however, impose limits on both futures and options contracts.

[6] As we define in more detail later, the total "price risk traded" is the sum of futures volume plus the sum of options volume on a given day, where the options volume is delta-weighted to arrive at a futures contract equivalent.

other policy considerations.

I. BACKGROUND

The spot or cash commodity market refers to the marketplace in which the trading or physical transfer of a commodity takes place. Producers and end-users who participate in the cash market for commodities normally have genuine business interests in the commodities, while those with speculative interests usually limit their trading to the derivatives markets. The cash markets for commodities are often dispersed geographically and deals are usually transacted in non-uniform (custom-tailored) lots.

A. Spot Market for Cotton in the United States

The spot market for cotton in the United States is generally quoted as a spread (often referred to as "the basis") above or below the nearby futures contract price.[7] Spot market prices are recorded and made publicly available by the United States Department of Agriculture (USDA) at the end of each day.[8] The USDA strives to report meaningful information; however, the spot market for U.S. cotton operates without any formal guidelines on location, time or size of trading unit and only informal requirements for reporting transactions (Anderson, Shafer and

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[7] The basis is normally calculated by subtracting the cash price from the futures price (the cash market normally trades at a discount to the futures due to the cost of carry) at a particular time and location. The basis changes regularly due to changes in transportation costs, storage and handling, interest rates, grade of cotton and various market forces such as supply and demand. The futures price of an asset can be related to its spot price by an expression of the form:

$$F = Se^{\alpha(T-t)}$$

where F= the futures price, S= the spot price, T= expiration date of the option, t= the current time, and α is a measure of the basis. The value of α can be either positive (implying futures prices are above spot) or negative (implying futures prices are below spot).

[8] The U.S. Cotton Futures Act of 1916 established the USDA system for determining and reporting spot cotton quotations. Price information is collected by market news reporters who regularly visit or call trade members within each designated spot market, analyze trade data and report <u>average</u> prices for the various qualities traded.

Haberer, 1996). The reported spot prices represent an average price for various qualities at multiple levels of production, i.e., they may include producer sales, inter-merchant trading, sales to mills and cooperative pooling.[9] As such, cotton market participants are forced to rely heavily on the quotations provided by the futures market and typically only look upon the USDA spot quotations as providing general price levels for a given day. Although spot and forward markets exist in other parts of the world, there is little or no interaction with the over-the-counter (OTC) market in the United States.[10]

In summary, unlike for other commodities (e.g., metals or energy complex), reliable spot price data for cotton are not always readily available. When the cotton futures market goes into limit, liquidity in the cash market dries up,[11] and other derivative markets must take the place of the futures market for price discovery since there are no foreign markets open to divert the activity. A more thorough description of the spot market for cotton in the United States can be found in Anderson, Shafer and Haberer (1996).

B. Futures Market for Cotton in the United States

The futures market serves as the primary source of price discovery for the U.S. cotton market on an intraday basis. Unlike in many other markets, equilibrium price data flow from the centralized futures market to the decentralized cash markets. Cotton futures are traded

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[9] Cooperative pools have been in existence in the U.S. cotton market since the late 1920's. Cooperative pools are farmer-owned cotton marketing cooperatives that are established to sell the members' crops through a centralized system. They are generally run by professional sales staffs who study and monitor cotton market trends and try to maximize selling opportunities for its members throughout the year.

[10] The U.S. Farm Bill does not allow for imports of cotton unless the average U.S. price for cotton is above the average world price for ten consecutive weeks.

[11] This assertion is supported by anecdotal evidence from market participants. The only exception noted was that the cash market activity did not always slow down uniformly, i.e., activity diminished more markedly during limit-down days than during limit-up days.

exclusively on the New York Cotton Exchange (NYCE), where futures prices are established through a system of open outcry.[12] The futures market creates a common denominator by providing a marketplace for a homogeneous product which serves the needs (to either hedge or speculate) of a diverse group of market participants. There are various grade, staple and micronaire specifications limiting the range of cotton that is tenderable on the NYCE; however, roughly two-thirds of the annual U.S. cotton crop normally qualifies for delivery.[13]

Cotton futures are traded in units of 50,000 pounds (approximately 100 bales) and prices are quoted in cents and hundredths of a cent per pound. The per-contract minimum price fluctuation is 1/100 of a cent (one "point") per pound below 95 cents per pound, and 5/100 of a cent (5 points) per pound at prices of 95 cents per pound or higher. Therefore, a point is worth five dollars per contract. Technically, the eligible trading months include the current month plus one or more of the next twenty-three succeeding months. However, trading is normally limited to the March, May, July, October, and December contract months, which are known as the active trading months.

An interesting phenomenon occurs in the cotton futures market on volatile days. The NYCE imposes trading restrictions on the underlying futures contracts when they reach arbitrarily defined price limits but allows all options on futures as well as futures spreads (defined below) to continue trading unconstrained by price limits. During the time period under which this analysis took place, all futures prices (with the exception of the spot month which had no limit in

[12] There are currently no other competing cotton futures exchanges in the world. Cotton yarn futures trade on the Nagoya Textile Exchange and the Osaka Textile Exchange in Japan; however, they are not viable hedging instruments due to the basis risk (explained in more detail in footnote 7) and different trading hours. This is in contrast to other commodity markets such as gold, oil or soybeans, where trading can shift to another geographic location such as the United Kingdom when a U.S. futures exchange imposes price limits (Cantor, 1989).

[13] The grade refers to the quality of the cotton, the staple to the length of the cotton leaf, and the micronaire to the thickness of its fiber.

its last 17 trading days) were subject to a 2 cent limit move above or below the previous day's settlement price. This limit expanded to 3 cents when any contract month settled at 95 cents or above or when three or more contract months closed in limit, and stayed at 3 cents for all contracts for the next three sessions.[14]

C. Options on Futures

Options on cotton futures are traded on the New York Cotton Exchange. Each contract represents an option on one NYCE futures contract. Strike prices are listed in one cent increments and prices are quoted in cents and hundredths of a cent. Options are not subject to daily price limits. The eligible trading months include March, May, July, October, and December. The nearest ten of the eligible months listed above are available for trading at any one time.

D. Spreads

Spreads are pairs of futures or options trades that are transacted by one trader simultaneously. A *futures spread* consists of the purchase of a futures contract with delivery one month and the sale of a futures contract with delivery in a different month, a strategy often referred to as a "calendar spread." Much of the risk in each position is essentially offset by the other, resulting in a position that reflects the price differential between the two delivery months. These spreads are not directly affected by directional movements in the market. An *options spread* can take many forms, depending on the options strategy being pursued, e.g., a synthetic futures, a straddle or a strangle. The trading prices of futures spreads and options spreads (defined as the price differential) are not subject to any form of price limits on the NYCE.

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[14] Effective January 15, 1996, the limits were expanded to 3 cents. They expand to 4 cents if any contract month settles at or above $1.10 per pound until no contract month settles at or above $1.10 (Cotton Price Limits-Rule 1.03).

II. DATA ON THE COTTON FUTURES AND OPTIONS MARKET

A. Primary data sources

Two primary data sources were utilized in this analysis. The NYCE kindly provided us with the *Time and Sales* and *Broker Reconciliation* reports which contain detailed trade data. This dataset covers the period September 1-29, 1995, for a total of 20 business days. September 1995 was selected since it was fairly representative of a typical month (in terms of volatility and trading volume) in the cotton futures market during the 1994-95 crop cycle.[15] We also used DRI/McGraw-Hill for opening and closing prices and volume data for the 1991-1995 period.

The *Time and Sales* report, which includes the opening prices and each price change that occurred during each day, was used as our primary source of futures trading data. **Table I** provides an example of the data contained in the *Time and Sales* report, which includes the trade date, contract expiration, futures price and time of trade. The futures price is quoted as the price per pound of cotton and in units of "points" (1/100 of a cent), so that a price of 8900, for example, represents 89 cents per pound of cotton. The *Time and Sales* report does not include the quantity traded. Volume data for futures trading was obtained from DRI which has daily summary figures organized by expiration date.

The *Broker Reconciliation* report, which includes every individual option trade and spread trade on futures and options for each trading day, was used as our primary source of options

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[15] Futures trading during the 1994-95 crop cycle was very unusual by historical standards in terms of volatility and number of trading sessions where price limits were in effect. Strong export demand in the United States during the latter half of 1994 and most of 1995, due to poor crops in other cotton producing nations, created a "classic" liquidity squeeze in the cotton market. A boll worm infestation in China drastically reduced China's cotton production, heavy rains caused severe crop damage in India and Pakistan, and a drought in New South Wales and Queensland hurt Australian production.

and spread data.[16] **Table II** provides an example of the data in the *Broker Reconciliation* report which is organized by trade date, contract expiration, strike price, an indication whether it was a call or a put (for options trades), options price or futures price (for futures spreads), volume traded and time of trade.

Figure 1 presents closing futures prices obtained from DRI covering the period from the beginning of 1991 through year-end 1995. It includes only the most actively traded contracts which are identified by contract expiration date. Figure 1 is intended to provide a graphical representation of the volatility of cotton futures prices over time. It is of interest to note the spikes that often occur when trading shifts from the July to the October contract. The cotton crop cycle or marketing season runs from August 1 to July 31. If the supply and demand for cotton remains relatively stable from one season to the next, the absolute change in price levels from the July contract (old crop) to the October contract (new crop) can be fairly small. However, when there is an imbalance one year, the jump can be dramatic, as in the spike downward in 1995.[17]

B. Derived data series

An additional data series (synthetic futures prices) was derived using the data in the *Broker Reconciliation* report. We derived a synthetic futures price series to examine the relationship between cotton futures prices and cotton options on futures prices using the put-call

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[16] The NYCE was careful in maintaining the confidential aspects of the data by not revealing the identity of the transacting broker.

[17] The forward curve for cotton is normally positively sloped i.e., the further out months are more expensive than the nearby contract due to carrying charges associated with storing cotton. The forward curve was inverted for most of 1995 due to the crop shortages, but reverted with the October contract. October is often referred to as the "swing" month since it is the first opportunity to trade the "new crop."

parity relationship for European options on futures.[18] Spread trades identified as synthetic futures (the simultaneous trading of a long call option and short put option with the same strike price and expiration) were used to derive a synthetic futures price. It can be shown via an arbitrage argument [19] that the following relationship holds:

$$C + K e^{-r(T-t)} = P + F e^{-r(T-t)} \qquad (1)$$

where: C = price of the call
P = price of the put
K = strike price
F = futures price
r = risk-free rate of return[20]
t = time to expiration.

During non-limit periods C, P, K, F, r, and t are all observable, so this formula can be used to gauge the efficiency of the market (which is done in Section IV.B below). During non-limit sessions, the price of the futures, F, is not observable, so that the put-call parity equation can be used to derive the synthetic futures price from the observed data by solving equation (1) for the synthetic futures price, F^*:

$$F^* = (C-P)e^{rt} + K \qquad (2)$$

Figure 2 displays the synthetic futures prices (denoted by a circle) and the actual futures prices (denoted by a square) for the December 1995 futures contract for each day in September

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[18] Options on cotton futures on the NYCE are American-style options. In theory, American-style options should be worth slightly more than a European option (assuming the risk-free rate of interest is positive and there is the chance that it will be optimal to exercise an American-style option early). However, there are currently no commonly used analytic formulas for valuing American-style options on futures and the derivation for European-style options is generally considered an adequate approximation.

[19] The put-call parity relationship is determined by arbitrage and is <u>not</u> based on any specific model of asset pricing dynamics such as log-normally distributed futures prices. We describe the arbitrage relationship in more detail in Section IV.B.

[20] The risk-free rate is defined as the continuously compounded short rate of interest, which we implement as the 3-month Libor rate. The same rate was used for all contracts since the Libor yield curve was relatively flat for the period within the study.

1995. One observation per half hour of trading was selected beginning at 10:30 a.m. and ending at 2:30 p.m., resulting in a maximum of nine observations per day. (Observations may be missing, if the futures were not trading or a synthetic futures trade did not take place during the half hour.) The horizontal lines for each trading day denote the allowable trading range for that day -- within a four cent or six-cent range centered at the previous day's close.[21] The vertical shaded areas show the times that the contract was "in limit" -- either trading was at the limit price or no trading took place due to the price limit.

Figure 2 reveals several interesting features in the data series. First, there is a very close match between the price of the actual futures trades and the price of the synthetic futures trades during non-limit (unshaded) times. We examine this relationship in more detail in Section IV.B. Second, there can be extreme differences between the price limits and the synthetic futures price during limit periods (such as September 12 and September 13). Third, there are sometimes days with up limit periods followed by days with down limit periods (such as September 18-19). Fourth, news events specific to cotton are very often responsible for the large jumps in prices from one day to the next. For example, on September 11, the USDA's monthly report on U.S. cotton production forecast a huge 7 percent or 1.5 million bale decline (the largest one-month change since they began such reports in 1960) in production from the previous month. The release of this news resulted in an 8 cent increase in the October futures contract between the closing futures price on September 11 and the synthetic futures price on September 12. Finally, there are days where futures trades take place at the price limit, even though the synthetic futures price is significantly outside the price limit range. Some market participants have a self-imposed mandate that restricts them from trading options and therefore

[21] Futures were subject to a 2 cent limit (4 cent range) around the previous day's close from September 1-September 14, a 3 cent limit (6 cent range) from September 15- September 27, and a 2 cent limit (4 cent range) for September 28 and 29.

they are confined to trading in the futures market, even if doing so implies trading at a disadvantageous price relative to the synthetic futures.

III. COMPETITION AND EFFICIENCY IN THE COTTON FUTURES AND OPTIONS MARKETS

This section explore the competition and efficiency in the cotton futures and options markets. Section IV.A examines the level of market concentration in the options spreads market, both during limit periods and non-limit periods. Section IV.B explores the efficiency in the futures and options markets by examining the arbitrage relationship between the futures contract and the synthetic futures trade when the futures are not in limit.

A. Broker concentration

An important component of a market's competitiveness is the extent of concentration among market participants. In general, a more highly concentrated market leads to less competitive pricing for the end user of the good or service. This section documents the extent of market concentration in the market for option spreads on cotton futures.[22]

Two measures of market concentration are used. First, we use the Herfindahl-Hirschman index (HHI), defined as:

$$HHI = \sum_{i=1}^{N} s_i^2 \tag{3}$$

where, for our purposes, s_i is the market share of the i^{th} broker and N is the total number of

[22] As mentioned previously, options spreads incorporate various portfolio strategies including synthetic futures, straddles, strangles, etc. As shown later in the paper (Figure 6), options spreads comprise 40 to 60 percent of all options trades. Data limitations do not allow us to study the market concentration in the futures and outright options market.

brokers. The HHI lies between zero and one. In a perfectly competitive industry, the HHI would approach zero, while in a monopolistic industry, the HHI would attain the maximum value of 1.0.

Second, we calculate the four-firm (CR4) and eight-firm (CR8) concentration ratios, which are defined as the percentage of total industry sales originated by the four or eight leading firms, respectively. In the case of the cotton options spreads market, it is the percentage of the total volume of option spreads trades transacted by the largest four or eight brokers.

Table III presents the results of the market concentration analysis. We divide the data series into two parts, the first in which the futures market was in limit the entire day (September 12, 13, and 21), and the second in which there were no limit moves (September 8, 22, and 25). The number of transacting brokers increases from an average of 50 on non-limit days to an average of 93 on limit days, as volume increases from an average of 4482 contracts to 13402 contracts. The HHI values range from approximately 0.05 to 0.12 on limit days to 0.07 to 0.17 on non-limit days. These ranges appear to fall in the average range of competitiveness for various representative industries in the United States (Scherer and Ross, 1990, p.77).

Table III also presents the CR4 and CR8 ratios for the six days we selected. For example, the CR4 ratios range in value from .372 to .458 on limit days to .458 to .588 on non-limit days. Like the HHI values noted above, the CR4 and CR8 ratios fall within the average range of competitiveness (Scherer and Ross, 1990, p.77). We also compared these results to data reported in the *1995 Central Bank Survey of Derivatives Market Activity*. The results suggest the competitiveness of the cotton futures market is similar to that of the over-the-counter market for foreign exchange and interest rate derivative contracts booked in the U.S., and more competitive than the OTC market for equity derivatives booked in the U.S.

Overall, these results suggest that the market for cotton options spreads is fairly competitive and likely becomes more competitive on limit days versus non-limit days, as the number of brokers and volume increase, and the concentration indices decline.

B. The arbitrage relationship between futures and synthetic futures

A main tenet of economic theory is known as the *law of one price*, which states that identical commodities should have identical prices. If the prices of two identical commodities were to differ, this *arbitrage opportunity* would allow a trader to buy the commodity at the cheaper price and sell the commodity at the more expensive price, thus netting a riskless profit. The existence of arbitrage is not consistent with an efficient financial market equilibrium. In equilibrium, identical commodities sell at identical prices, and there are no arbitrage opportunities. In this section, we test whether the market for cotton futures and options allows for a certain type of *arbitrage opportunity.*

More specifically, we empirically test whether the market for cotton futures and options exhibits this type of arbitrage opportunity during non-limit periods by comparing the actual futures prices, denoted F_t, with the synthetic futures prices, denoted F_t'. A synthetic futures trade provides the same cash flow as a genuine futures contract, and therefore, via the arbitrage argument given above, should have exactly the same price as the futures contract. The synthetic futures price for each trade is derived from the options price using formula (2) from Section III. The corresponding actual futures price is estimated as the average futures prices of all the futures that were reported during the same minute as the synthetic futures was reported. We drop from the sample of matched synthetic futures and actual futures all observations where the actual futures price was at the limit price for the day, in order to eliminate prices that were not indicative of the equilibrium price of the futures contract.[23] Over the 20 trading days in

[23] Recall that, when the futures are in limit, the futures spreads continue to trade unconstrained by the price limit. The exchange records each leg of the spread separately, but the only economically important number is the differential between the prices. The exchange never records the futures price on either leg of the spread outside

September 1995, there are 235 observations that meet the criteria for simultaneous actual futures and synthetic futures.

The no-arbitrage condition between the actual futures and the synthetic futures implies that the futures price should equal the synthetic futures price for all times t for which both an actual futures and a corresponding synthetic futures trade:

$$F_t^* = F_t.$$

However, this equation will not hold with strict equality for two reasons. First, the times of the actual futures trade and synthetic futures trade will not exactly coincide (a situation referred to as "nonsynchronous trading") because there is a random delay (from one to five minutes) from the time the trade is executed to the time it is reported. In addition, the equality will not hold precisely because both the futures and the options have bid-ask spreads that are not explicitly taken into account here. The bid-ask spreads add a measure of imprecision to the equation. Therefore, in order to allow for these imperfections, we regress the actual futures prices on the synthetic futures prices for all contract expirations:

$$F_t^* = \beta_0 + \beta_1 F_t + \epsilon_t$$

This regression should yield a coefficient of zero for β_0 and a coefficient of one for β_1 if the market were efficient. The error term ϵ_t is meant to capture the effect of nonsynchronous trading and the bid-ask spreads, and is assumed to have zero mean and constant variance.[24]

The condition of no arbitrage also implies that the changes in the actual futures prices should equal the change in the synthetic future prices:

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the boundary of the price limits, even if the equilibrium price of one of the contracts would have been outside the limit if the limit did not exist. Therefore, the spread trades that are recorded at the limit price must be eliminated from the data set for the arbitrage test, because these prices at the limit do not represent the price at which each leg individually can be transacted.

[24] All of the regressions in this paper were re-done using White's (1980) heteroskedastic (nonconstant variance) adjusted standard errors, and all of the results were robust to this adjustment.

$$\Delta F_t^* = \Delta F_t$$

This condition, again, will not hold with exact equality, due to the problems of nonsynchronous data and bid-ask spread. Therefore, we regress the changes in actual futures prices and synthetic futures prices for the most active expiration month,

$$\Delta F_t^* = \beta_0 + \beta_1 \Delta F_t + \epsilon_t$$

which should also yield a coefficient of zero for β_0 and a coefficient of one for β_1. Therefore, for both regressions, the null hypothesis that the market exhibits no arbitrage opportunity implies that $\beta_0 = 0$ and $\beta_1 = 1$, which we test empirically.

Figure 3 presents graphically the relationship between the actual futures prices and the synthetic futures prices for our data set of 235 observations. The regression results (with standard error in parentheses)

$$F_t^* = \underset{(27.76)}{-30.02} + \underset{(0.0032)}{1.0033}\, F_t$$

$$\bar{R}^2 = 0.9979 \qquad RMSE = 22.12$$

indicate that, consistent with the absence of arbitrage, the β_0 estimate of -30.02 is not statistically significantly different from zero and the β_1 estimate of 1.0033 is not statistically significantly different from one. Additionally, the high $\bar{R}^2$ of 0.9979 shows the tightness of fit of the regression.

If market participants were using synthetic futures contracts to replicate or hedge actual futures contracts, they would be more interested in the relationship of the <u>changes</u> in these prices more than in the relationship of the <u>levels</u>. **Figure 4** presents the relationship between the *changes* in the synthetic futures price and the *changes* in the actual futures price for 207 changes in price for the December 1995 contract. These regression results (with standard errors in parentheses)

$$\Delta F_t^* = -0.128 + 1.0099\, \Delta F_t$$
$$(1.883) \qquad (0.024)$$

$$\bar{R}^2 = 0.8957 \qquad RMSE = 27.08$$

also indicate that the β_0 estimate of -0.128 is not statistically significantly different from zero and the β_1 coefficient of 1.0099 is not statistically significantly different from one. Additionally, the $\bar{R}^2$ of 0.8957 shows a strong positive relationship between changes in the synthetic futures price and changes in the actual futures price.

In summary, Figures 3 and 4 and the corresponding regression results support the no-arbitrage conjecture for the cotton futures market during times of no price limits. With the exception of some sample variation, most likely due to nonsynchronous trading and bid-ask spreads, the theoretically predicted relationships between actual futures and synthetic futures appear to hold. This strong relationship between the prices for futures contracts and the synthetic futures options strategy provides evidence of an efficient market between cotton futures and options when the futures are not in limit.

IV. UNIVARIATE ANALYSIS OF TRADING VOLUME

In this section, we explore how the futures price limits in the cotton market affect the overall volume in cotton trading at the NYCE. In principle, the market volume traded could decline significantly as price transparency is reduced by the price limit; trading could switch from one futures contract to futures-based trading strategies; or trading could switch from the futures contracts to a variety of options-based strategies, including high-delta options (defined below), synthetic futures, other spread trades, or individual options. First, we document how futures trading decreases as price limits become binding on the futures contracts. Second, we explore the response to these limits in terms of substitution from contracts in limit to those not in limit.

Third, we develop a measure of aggregate trading across futures and options to determine whether the aggregate volume of cotton traded is influenced by the imposition of trading limits.

A. The effect of price limits on futures volume

Figure 5 presents the number of futures contracts traded (represented by bars and using the left scale) and the fraction of the day in limit (represented by the line and using the right scale), for the December 1995 contract for each trading day in September 1995. The fraction of day in limit is defined as the ratio of the number of minutes in a trading session that the futures traded at its limit to the total number of minutes in a trading session (250 minutes for cotton futures). The bar representing the number of futures contracts traded is divided into contracts that were traded as calendar spread trades and those that were not. The total number of contracts traded is significantly negatively correlated with the fraction of day in limit. The univariate regression of the fraction of day in limit on the number of futures contracts traded yields the results (standard errors are in parentheses):

$$\textit{Number of futures contracts}_t = \underset{(758)}{7671} - \underset{(1591)}{5113}\ \textit{Fraction of day in limit}_t$$

$$\bar{R}^2 = 0.329 \qquad RMSE = 2656$$

The negative and significant coefficient on the *Fraction of day in limit* variable implies that a significant decline in futures contracts traded occurs as the fraction of the day in limit increases. The regression suggests that, on average, 7671 contracts should trade on a day when the futures is not in limit at all (*Fraction of day in limit* = 0) and 2558 contracts should trade on a day when the futures is in limit all day (*Fraction of day in limit* = 1).

One possible reaction by market participants to a futures contract hitting its limit price is to use a futures-based trading strategy. For example, one way for a trader to gain exposure to the December futures contract that is in limit is to purchase a March futures contract that is not in limit and to simultaneously short the December-March spread contract.[25] A univariate regression of the number of overall futures spread contracts traded on the fraction of the day that the most active contract (December 1995 expiration) was in limit yields the following results (with standard errors in parentheses):

$$\textit{Number of futures spread contracts}_t = \underset{(762)}{1537} + \underset{(457)}{329}\ \textit{Fraction of day in limit}_t$$

$$\bar{R}^2 = 0.023 \qquad RMSE = 732$$

This regression result suggests that there is not significant substitution from futures in limit to other futures-based strategies, as the coefficient on the independent variable *Fraction of day in limit* is not significantly different from zero. This result is not entirely surprising, since when one futures contract goes into limit, other contracts tend to follow, thus rendering this strategy infeasible.

Further analysis indicates that even when the most actively traded contract is in limit all day while others are not, there is only a mild futures-to-futures substitution. For example, on September 13, the December 1995 through October 1996 futures contracts were in limit all day while the December 1996 contract was not in limit at any time during the day. The December 1995 contract traded only 540 contracts, down from an average of almost 7000 during non-limit days, while the December 1996 contract traded only 673, up from an average of 120 contracts on days when the earlier contracts were not in limit. A drop of 6500 December 1995 contracts coincided with an increase of only 550 December 1996 contracts. So, even during the

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[25] As mentioned previously, futures spreads, like options and options spreads, are not subject to price limits.

infrequent periods where one futures contract is in limit and others are not, there is not substantial futures-to-futures substitution of trading.

B. The effect of price limits on options volume

Figure 6 presents the number of options contracts traded (bars and left scale) and the fraction of the day in limit (lines and right scale), for the December 1995 contract for each trading day in September 1995. The bar representing the number of options contracts traded is divided into three parts: synthetic futures contracts, other spread trades, and outright options contracts. The total number of contracts that traded is significantly positively correlated with the fraction of day in limit. The univariate regression of the fraction of day in limit on the number of options contracts traded yields the results (standard errors are in parentheses):

$$\underset{}{\textit{Number of options contracts}_t} = \underset{(913)}{4784} + \underset{(1917)}{9272}\ \textit{Fraction of day in limit}_t$$

$$\bar{R}^2 = 0.541 \qquad RMSE = 3162$$

Therefore, a significant increase in options contracts traded occurs as the fraction of the day in limit increases. The regression suggests that, on average, 4784 contracts should trade on a day when the futures is not in limit at all (*Fraction of day in limit* = 0) and 14,056 contracts should trade on a day when the futures is in limit all day (*Fraction of day in limit* = 1).

Interestingly, each of the three categories of options-based strategies (synthetic futures, other spread trades such as call spreads and straddles, and individual options) is significantly positively correlated with the fraction of day in limit. We now explore some of the advantages and disadvantages of various options-based strategies as substitutes for futures when limits are in effect.

Trading could switch from futures to high-delta options. High-delta options have price sensitivities to changes in futures prices that closely resemble the futures itself. A single high-delta option has the advantage over combinations of low-delta options in that, like the futures itself, high-delta options are not significantly affected by volatility (i.e., high-delta options have low "vega risk"). The major difference between a high-delta option and a futures contract is that, while the futures requires no upfront premium, the high-delta option generally requires a significant upfront premium. Tables IV and V present evidence that there is not a significant substitution between futures and high-delta options. **Table IV** displays the distribution of the ratio of underlying futures price to the call options' strike prices (the "moneyness ratio") on three days that the futures was not in limit at all (September 8, 22 and 25) and three days when the futures was in limit all day (September 12, 13 and 21). This moneyness ratio is the major determinant of an option's delta.[26] **Table V** displays similar information for put options. While the average moneyness ratios indicate that the average delta of a traded option increases as more of the day is in limit, careful consideration of the distribution of the moneyness ratio indicates that, in fact, a lower percentage of high-delta options trade on limit days. The increase in average moneyness is the result of decreased trading in out-of-the-money options and an increased trading in at-the-money options. Market participants are not trading more high-delta options in substituting options for futures.

Rather than using high-delta options, traders are using synthetic futures and other options spread trades to replicate the futures that are in limit. The two legs of a synthetic futures

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[26] This ratio is monotonically related to the option's delta. Given the times to expiration and interest rate environment in the market for cotton in September 1995, for calls, a ratio of 0.9 corresponds to a delta of approximately .25, a ratio of 0.95 corresponds to a delta of approximately .40, a ratio of 1.0 corresponds to a delta of approximately .5, a ratio of 1.05 corresponds to a delta of approximately .65, and a ratio of 1.1 corresponds to a delta of approximately .75. For puts, this scale is inverted, with a ratio of 0.9 corresponding to a delta of approximately -.75, etc.

contract each has a delta of approximately 0.5, explaining the increase in the use of options with such deltas. The synthetic futures strategy is quite similar to the outright futures contract in that it is not exposed to volatility changes, and has the advantage over high-delta options in that it requires little or no up-front premiums. In addition to spread trades, limit days are accompanied by significant increases in individual options, which is another method of gaining exposure similar to that of a futures contract. For example, two long options contracts with a delta of 0.5 have the same price exposure as the futures contract (but have additional volatility exposure). It may be the case that some of the individual options trading is recorded as individual options but in actuality may be a synthetic futures (or other options-based strategy) that has been "legged into," i.e., each leg of the exposure (the call leg and the put leg) is done with separate brokers, in which case the trade would not get recorded as a spread trade, but rather as two individual options trades.

C. The effect of price limits on total cotton risk traded

The evidence from the graphed data and supporting univariate regressions clearly indicates that futures volume decreases and options volume increases as the futures price limit is binding for a larger fraction of the day, with a variety of options-based strategies replacing the in-limit futures contract. How complete is the substitution of trading from futures to options? In order to address this question, a measure of the total price risk of cotton that is traded in a day is needed. A reasonable way of aggregating the risk of futures and options that trade on the exchange is to sum the futures volume and the options volume, where the options are weighted by the absolute value of its own *delta*:[27]

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[27] The delta of an option is the change in price that the option will experience if the underlying futures contract increases by one. A futures contract (as well as a synthetic futures contract) has a delta of one. The delta of an options contract will be between zero and one. When the strike price of the options contract is near the futures

$$\textit{Total cotton price risk traded}_t \doteq \sum_{i=1}^{N_{Futures}} V^i_{Futures} + \sum_{i=1}^{N_{Options}} V^i_{Options} \times |Delta^i|$$

where $V^i_{Futures}$ represents the volume of futures contracts traded in trade *i*, $V^i_{Options}$ represents the volume of options contract traded in trade *i*, $N_{Futures}$ is the total number of transactions involving futures contracts, $N_{Options}$ is the total number of transactions involving options contracts, and $Delta^i$ is the delta of the option in trade *i*.

Figure 7 presents the futures-equivalent number of contracts traded (bars and left scale) and the fraction of day in limit (line and right scale) for the December 1995 contract for each trading day in September 1995. The regression of the *Total cotton price risk traded* on the *Fraction of day in limit* indicates that these two variables are not significantly correlated (standard errors are in parentheses):

$$\textit{Total cotton price risk traded}_t = \underset{(922)}{9372} - \underset{(1936)}{731}\ \textit{Fraction of day in limit}_t$$

$$\bar{R}^2 = -0.047 \qquad RMSE = 3194$$

This result is evidence that the existence of price limits does not significantly limit the total cotton price risk traded. There appears to be a seamless transition in volume from the contracts that are in limit to the options market, to the extent that the total volume traded on limit days is not significantly different from the total volume traded on a day that was not in limit at all.

D. Section summary

Price limits could potentially lead to several market responses suggested earlier.

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price, its delta is approximately one-half. By summing the futures and the delta-weighted options, we arrive at the equivalent number of futures that are represented by the total volume of trading. We do not distinguish between a negative and positive delta, because the sign of the delta depends on whether one is the buyer or the seller of the option. For example, a call option has a positive delta for the buyer, but a negative delta for the seller. Therefore, in measuring total cotton price risk traded, we sum futures traded and the options traded, where the options are weighted by the absolute values of their deltas

Empirically, we find that futures volume drops significantly while options volume increases significantly, when price limits are in effect. The increase in options trading does not coincide with trading in high-delta options, but rather does coincide with an increase in synthetic futures trading, other options spread trading and with individual options trading. There does not appear to be a significant impact of the price limit on the total cotton price risk traded, but rather only a substitution from the futures market to the options market. The efficiency of the options market as represented by the close fit between actual futures and synthetic futures documented earlier may help explain the willingness of market participants to transfer their volume over to the options market when the futures go into limit.

We now turn from this univariate analysis to a multivariate analysis to determine the importance of other variables on the volume of futures and options traded during limit and non-limit periods.

V. MULTIVARIATE ANALYSIS OF TRADING VOLUME

This section explores more fully the effect of price limits on futures volume, options volume and total volume traded by using three explanatory variables in the multiple regressions to help explain the patterns of the volume of contracts traded in the futures market, in the options market and in the aggregate.

First, the *fraction of day in limit*, as mentioned earlier, is the fraction of the trading day (out of the 250 minute daily trading session) that the futures price trades at the limit or does not trade because the equilibrium price (measured by the synthetic futures price) is outside the limit.

Second, *volatility* is a measure of the price variability during the trading day. In most financial markets, a positive relationship has been documented between volume and volatility. More volatile days are associated with important news events, and the news, as well as the resulting movement in prices, tends to give market participants reasons to trade to change their exposures. The daily volatility estimate (derived by Garman and Klass, 1980), approximates daily volatility on date t as a function of the closing price on date t-1 and the opening price, maximum price and minimum price on date t.[28] For our purposes, we substituted the synthetic futures price for the actual futures price for the fraction of the day that the futures was in limit to determine each of the inputs into the price volatility.

Third, the *distance from the price limit to the equilibrium price* in the absence of the price limit (as measured by the average synthetic futures price) is used as another explanatory variable. If options have higher transactions costs than futures, then a trader may be more willing to trade the futures at the limit price than to trade the synthetic futures at a slightly more advantageous price, if the price advantage is less than the differential in transactions costs. In addition, cotton traders may be less willing to trade on days where the futures price has moved significantly outside the price limit boundaries when compared to days where the futures price barely breaches the price limits, due to the increased lack of transparency on the days with larger price moves.[29] This measure is implemented by measuring the average difference

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[28] The formula that Garman and Klass (1980) derive is as follows. Let C_t represent the closing price on date t, O_t represent the opening price on date t, H_t represent the maximum (high) price on date t, L_t represent the minimum (low) price on date t, $u_t = H_t - O_t$, $d_t = L_t - O_t$, and $c_t = C_t - O_t$. Then the estimate of volatility on date t is:

$$\hat{\sigma}^2 = 0.12\,\frac{(O_t - C_{t-1})^2}{f} + 0.88\,\frac{\hat{\sigma}^{*2}}{(1-f)}$$

where

$$\hat{\sigma}^{*2} = 0.511(u_t - d_t)^2 - 0.019[c_t(u_t + d_t) - 2u_t d_t] - 0.383c_t^2$$

and f is the fraction of the day that the contract trades (0.1736 in the case of cotton futures). We chose to use this formula over calculating the volatility estimate from the intraday data because such an estimate from intraday data will be function of the size of the bid-ask spread, which is not likely to remain constant between limit days and non-limit days. The Garman-Klass (1980) estimate is much more robust to differences in bid-ask spread.

[29] For example, compare the small breach of the price limits on September 7 and the large breach of the price limit on September 12 in Figure 2. Traders may be more willing to rely on the prices from the synthetic futures market on September 7 than September 12 due to the difference in the size of the breach of the price limits.

between the synthetic futures price and the price limit, for those observations that were outside the price limits. Therefore, on days in which price limits were not triggered, this value would be zero, and on days that were in limit all of the time, this value would be the (absolute value of the) difference between the average synthetic futures price and the price limit that had been violated.[30]

Tables VI, VII and VIII report the results of six specifications of the ordinary least squares (OLS) regression of the form:

$$\textit{Volume traded}_t = \beta_0 + \beta_1 \textit{ fraction of day in limit}_t + \beta_2 \textit{ volatility}_t + \beta_3 \textit{ distance outside limit}_t.$$

where *Volume traded$_t$* is measured by three different dependent variables on date *t*: *Futures contracts traded$_t$*, *Options contracts traded$_t$*, and *Total volume traded$_t$*. The first three specifications in each table represent each of the independent variables by itself (univariate regressions). The other three specifications represent combinations of the independent variables (multiple regressions).

<u>Futures volume:</u> The univariate regressions for futures volume (Models 1, 2 and 3 in **Table VI**) show that the fraction of day in limit and the distance from the limit price to the synthetic price are significantly negatively related to futures volume. A larger fraction of the day in limit leads to fewer futures contract traded, and a larger distance from the limit price to the synthetic price leads to fewer futures contracts traded. The multiple regressions (Models 4, 5, and 6 in Table VI)

[30] An additional independent variable, the *number of days since the futures last traded unconstrained by the price limits*, is introduced to gauge potential "pent-up" demand. Pent-up demand to trade cotton futures may be driven by traders who can only use the futures market due to institutional restrictions. In Figure 3, for example, the December 1995 futures contract was in limit for two straight days -- from the close on September 11 to the open on September 14. The inclusion of this variable tests whether there is unexpectedly high demand for futures when the futures market opens after being in limit for a period of time. The coefficients on this variable were never significantly different from zero (at the 10% level) and the inclusion of this variable in the regressions never changed the sign or the significance levels of the coefficients of the other independent variables.

support the significance of all of the independent variables simultaneously. The volatility enters the regression as significant when the other independent variables are taken into consideration.

Options volume: The univariate regressions for options volume (Models 1, 2 and 3 in **Table VII**) show that the fraction of day in limit, the volatility and the distance from the limit price to the synthetic price are significantly positively related to options volume. A larger fraction of the day in limit leads to more options contract trading, a larger distance from the limit price to the synthetic price leads to more options contracts traded, and a larger volatility leads to more options contracts trading. The multiple regressions (Models 4, 5 and 6 in Table VII) support the significance of the fraction of day in limit, but show that the volatility and the distance from the limit price to the synthetic futures price do not have an independent effect on the volume of options traded, after the fraction of day in limit is taken into account.

Overall volume: The univariate and multiple regressions for total volume of cotton traded (Models 1-6 in **Table VIII**), defined again as the sum of the futures volume plus the delta-weighted options volume, show none of the explanatory variables individually, and no combination of these variables, are able to explain a significant portion of the variability of the total volume of cotton traded. The only variable that comes into the regressions as significantly different from zero is the distance from the limit to the synthetic futures price in Model 6, which contains all of the explanatory variables; it is significant at the 10% level, but the entire regression is not significant at the 10% level. The price limits and the characteristics of the price limits that are impounded in these explanatory variables are uncorrelated with the total amount of cotton price risk that was traded during the month of September 1995.

The lack of explanatory power of any of the variables included in the regression raises two questions that are difficult to address directly. First, what is the true impact of price limits on the trading of cotton risk, if an equivalent exposure is easily attained and an equivalent level of trading transfers from the futures market to the alternative market? The fact that none of the explanatory variables enter the *Overall Volume* regression as significant suggests that the impact on trading volume is most likely only cosmetic, shifting trading from one venue -- the futures pit -- to another venue -- the options pit. If the objective of the price limits is to limit trading during volatile periods, which is the focus of most of the theoretical arguments in support of trading limits, the objective is not being fulfilled.

Second, shouldn't we be able to explain some of the variation in volume? For example, as mentioned previously, trading volume for many traded assets is positively correlated with volatility; why not for cotton? Two further tests were performed to estimate the impact of futures volatility on futures volume in the absence of the futures price limits. First, the futures price limits are lifted in the last 17 days of trading for each of the futures contracts. (One effect of lifting the price limits is to allow the settlement price to converge to the spot price as the expiration of the contract approaches.) Attempts to estimate the relationship between volume and volatility on futures during these periods were unsuccessful, because as the expiration date of the futures contracts approach, the volume quickly diminishes to near zero. The low volume is presumably dominated by hedgers unwinding their positions so as not to deliver the actual cotton at expiration, and arbitrageurs ensuring the futures and spot price remained aligned. Therefore, we consider the results from a statistical study of the volume-volatility relationship during the last 17 days of futures trading to be unrepresentative of the broader relationship between volume and volatility. Second, we attempted to estimate the relationship between volume and volatility solely on days in which the futures did not go into limit at all. For the calendar year 1995, we ran the regression

$$\textit{Futures contracts traded}_t = \beta_0 + \beta_1 \textit{ Volatility}_t$$

on each contract using daily data, eliminating the last 17 trading days of a contract (for reasons given above) and days in which the futures experienced any limit period. The relationship was not significant for any of the contract expirations studied (from May 1995 to May 1996). However, this evidence of an absence of a volume-volatility relationship is not strong evidence, because the exclusion of large values in the explanatory variable (in this case, volatility on days that experienced any limit periods), in general will decrease the likelihood of discovering a significant relationship, even if such a relationship exists. It remains unclear why the relationship between volume and volatility, that is so clearly documented for other assets, does not appear in the market for cotton futures.

VI. POLICY CONSIDERATIONS AND CONCLUSIONS

This paper highlights several points about the effects of exchange-mandated trading limits on the level of market activity. We found, in the case of cotton futures, trading volume can easily shift from one contract to another, and that the aggregate level of trading appears unaffected by the price limits.

A broad implication of this result is that trading volume can potentially shift to another domestic exchange, to a foreign exchange, or to the OTC market, if an exchange attempts to unilaterally impose trading limits on its participants. This empirical finding strongly supports the conclusion of the Brady Commission Report (1988) that, in order for trading limits to be effective, regulations need to be coordinated across markets. If the objective is to limit trading, then coordination across market venues is critical.

While trading volume does readily shift from one market to another, an interesting question arises concerning the effect of price limits on the quality of price quotes and trading during limit periods versus non-limit periods. For example, the trading limits could produce some forms of market inefficiencies, because the shift from futures contracts to options-based strategies potentially shifts the price discovery mechanism and the transfer of risk function from the futures market to the options market where there is less transparency.[31] This phenomenon could serve as the focus of future research.

Another important policy consideration is that not all market participants are influenced in the same way by the imposition of a price limit. As mentioned previously, some investors may be constrained by individual institutional rules that forbid them from trading options. These investors have no choice but to trade the underlying futures contract when the limits are in effect (at a price dictated by the limit), even though they could potentially receive a more advantageous price trading the equivalent synthetic futures.

In order to fully evaluate any trading limit, including price limits, one needs to address the *intended* effect of the trading halt -- *why* the exchange imposes trading limits. The focus of this paper, however, is strictly on the observable effects of price limits on trading volume. We conclude that their effect on trading volume is, at most, minimal.

[31] The price of the underlying (the futures contract) becomes an unobservable variable along with the volatility of the underlying, which is always unobservable.

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Table I

Futures Data

This table provides an example of the data that are provided in the *Time and Sales* file for the futures contracts provided by the New York Cotton Exchange.

Trade date	Contract Month	Contract Year	Time	Price
19950901	10	1995	1030	8445
19950901	10	1995	1030	8440
19950901	10	1995	1030	8430
19950901	10	1995	1039	8360
19950901	10	1995	1039	8350
....				

Table II

Options Data

This table provides an example of the data that are provided in the *Broker Reconciliation* file for all options contracts and futures spread trades provided by the New York Cotton Exchange.

Trade Date	Contract Month	Contract Year	Strike	Call/ Put	Premium	Volume	Time	Trade Number
19950901	10	1995	7000	C	1510	6	1121	50019
19950901	10	1995	7000	C	1600	7	1250	50013
19950901	10	1995	7300	P	5	1	1030	50001
19950901	10	1995	7600	P	12	1	1134	50056
19950901	10	1995	7600	P	7	10	1212	50007
....								

Table III

Concentration Ratios for Cotton Brokers

(Option Spreads Data)

This table shows different measures of broker concentration in the options spreads market in September 1995. The data are broken into limit days (September 12, 13, and 21) and non-limit days (September 8, 22, and 25). The Herfindahl-Hirschman index is defined as the sum of the squared market shares of each of the brokers, and the 4-broker and 8-broker concentration ratios are the fraction of all trades that involve the most active 4 and 8 brokers, respectively. The volume of option spreads is defined as the number of options contracts that traded that were designated as spread trades, and the total number of transacting brokers is defined as the number of brokers that were involved in at least one options spread trade during the day.

	Limit Days			Non-Limit Days		
	Sept 12	Sept 13	Sept 21	Sept 8	Sept 22	Sept 25
Herfindahl-Hirschman Index[1]	0.0569	0.1189	0.0615	0.0891	0.0709	0.1683
4-Broker Ratio	.372	.458	.441	.496	.458	.588
8-Broker Ratio	.607	.609	.610	.680	.669	.796
Volume of Option Spreads	9296	12841	13683	2094	5876	5477
Total # of Transacting Brokers	85	88	106	50	57	43

The Herfindahl index measures the amount of market concentration in an industry. The index number lies between zero and one, where zero represents perfect competition.

Table IV

Distribution of Moneyness Ratios Traded on Limit Days and Non-Limit Days, CALL OPTIONS

Distribution of moneyness ratios for three limit days and three non-limit days, where the moneyness ratio is defined as the ratio of the most recent futures price (or synthetic futures price for limit days) divided by the strike price of the option:

Moneyness Ratio R = Futures price / Strike price

Date	Fraction of day in limit	Average Ratio	R<0.90 $\|\Delta\| < 0.25$	0.90<R<0.95 $0.25<\|\Delta\|<0.35$	0.95<R<1.0 $0.35<\|\Delta\|<0.5$	1.0<R<1.05 $0.5<\|\Delta\|<0.65$	1.05<R<1.1 $0.65<\|\Delta\|<0.75$	R>1.1 $\|\Delta\|>0.75$
Sept 8	None	0.92	60.9	27.2	4.8	6.9	0.1	0.0
Sept 22	None	0.99	10.8	26.8	20.7	19.5	11.0	11.1
Sept 25	None	0.96	34.7	23.1	37.1	1.9	0.0	2.9
Sept 12	All	1.00	4.8	14.5	22.1	53.8	2.5	2.1
Sept 13	All	0.98	5.0	38.6	13.3	41.1	0.7	1.2
Sept 21	All	1.01	1.3	25.3	21.3	29.0	0.0	5.5

Table V

Distribution of Moneyness Ratios Traded on Limit Days and Non-Limit Days, PUT OPTIONS

Distribution of moneyness ratios for three limit days and three non-limit days, where the moneyness ratio is defined as the ratio of the most recent futures price (or synthetic futures price for limit days) divided by the strike price of the option:

Moneyness Ratio R = Futures price / Strike price

Date	Fraction of day in limit	Average Ratio	R>1.1 $\|\Delta\|<0.25$	1.05<R<1.1 $0.25<\|\Delta\|<0.35$	1.0<R<1.05 $0.35<\|\Delta\|<0.5$	0.95<R<1.0 $0.5<\|\Delta\|<0.65$	0.9<R<0.95 $0.65<\|\Delta\|<0.75$	R<0.9 $\|\Delta\|>0.75$
Sept 8	None	1.04	25.1	12.7	29.8	30.0	2.3	0.0
Sept 22	None	1.03	31.9	39.9	18.6	18.6	0.0	0.0
Sept 25	None	1.06	65.2	13.8	13.9	2.0	5.1	0.0
Sept 12	All	1.04	12.9	21.6	54.0	11.6	0.0	0.0
Sept 13	All	1.03	27.3	12.4	20.9	39.3	0.0	0.0
Sept 21	All	1.04	26.9	33.2	22.5	17.4	0.0	0.0

Table VI

Regressions of Futures Volume on Possible Explanatory Variables

This table reports the results of six specifications of the following regression:

$$\textit{Futures volume traded}_t = \beta_0 + \beta_1 \textit{ fraction of day in limit}_t + \beta_2 \textit{ volatility}_t + \beta_3 \textit{ distance outside limit}_t$$

Models 1-3 are the univariate regressions with one independent variable at a time, while Models 4-6 are the multiple regressions with combinations of the independent variables

FUTURES		Model					
		Univariate regressions			Multiple regressions		
	General effect	1	2	3	4	5	6
Intercept	Positive	+ 7671 ***	+ 6810 ***	+ 6800 ***	+ 7669 ***	+ 7539 ***	+ 6634 ***
Fraction of day in limit	Negative	- 5113 ***			-5125 **	- 3457 *	- 3183 *
Volatility	Positive		- 125		1		+ 303 **
Distance from limit to average synthetic price	Negative			- 18.69 ***		- 10	- 33 **
$\bar{R}^2$		0.329	0.051	0.285	0.290	0.355	0.471
F-value for entire regression		10.323 ***	2.014	8.558 ***	4.567 **	6.227 ***	6.643 ***

* indicates significance at the 10% level
** indicates significance at the 5% level
*** indicates significance at the 1% level

Table VII

Regressions of <u>Options</u> Volume on Possible Explanatory Variables

This table reports the results of six specifications of the following regression:

$$\textit{Options volume traded}_t = \beta_0 + \beta_1\ \textit{fraction of day in limit}_t + \beta_2\ \textit{volatility}_t + \beta_3\ \textit{distance outside limit}_t$$

Models 1-3 are the univariate regressions with one independent variable at a time, while Models 4-6 are the multiple regressions with combinations of the independent variables

OPTIONS		Model					
		Univariate regressions			Multiple regressions		
	General effect	1	2	3	4	5	6
Intercept	Positive	+ 4784 ***	+ 6358 ***	+ 6763 ***	+ 6357 ***	+ 4786 ***	+ 4841 ***
Fraction of day in limit	Positive	+ 9272 ***			+ 9325 ***	+ 9253 ***	+ 9236 ***
Volatility	None		+ 225 *		- 4		- 18
Distance from limit to average synthetic price	None			+ 22.75 **		0	+ 1
$\bar{R}^2$		0.541	0.106	0.182	0.514	0.514	0.484
F-value for entire regression		23.385 ***	3.255 *	5.231 **	11.045 ***	11.043 ***	6.936 ***

* indicates significance at the 10% level
** indicates significance at the 5% level
*** indicates significance at the 1% level

Table VIII

Regressions of Overall Volume on Possible Explanatory Variables

This table reports the results of six specifications of the following regression:

$$\textit{Total volume traded}_t = \beta_0 + \beta_1 \textit{ fraction of day in limit}_t + \beta_2 \textit{ volatility}_t + \beta_3 \textit{ distance outside limit}_t$$

Models 1-3 are the univariate regressions with one independent variable at a time, while Models 4-6 are the multiple regressions with combinations of the independent variables

AGGREGATE VOLUME		Model					
		Univariate regressions			Multiple regressions		
	General effect	1	2	3	4	5	6
Intercept	Positive	+ 9371***	+ 9264 ***	+ 9442 ***	+ 9380 ***	+ 9235 ***	+ 8355 ***
Fraction of day in limit	None	- 731			- 686	+ 970	+ 1236
Volatility	None		- 21		- 4		+ 295
Distance from limit to average synthetic price	None			- 8		- 11	- 33 *
$\bar{R}^2$		-0.047	-0.052	0.013	-0.108	-0.036	0.05
F-value for entire regression		0.143	0.053	1.240	0.068	0.667	1.373

* indicates significance at the 10% level
** indicates significance at the 5% level
*** indicates significance at the 1% level

FIGURE 1

DAILY CLOSING PRICES FOR MOST ACTIVELY TRADED COTTON FUTURES CONTRACT

1991 - 1995

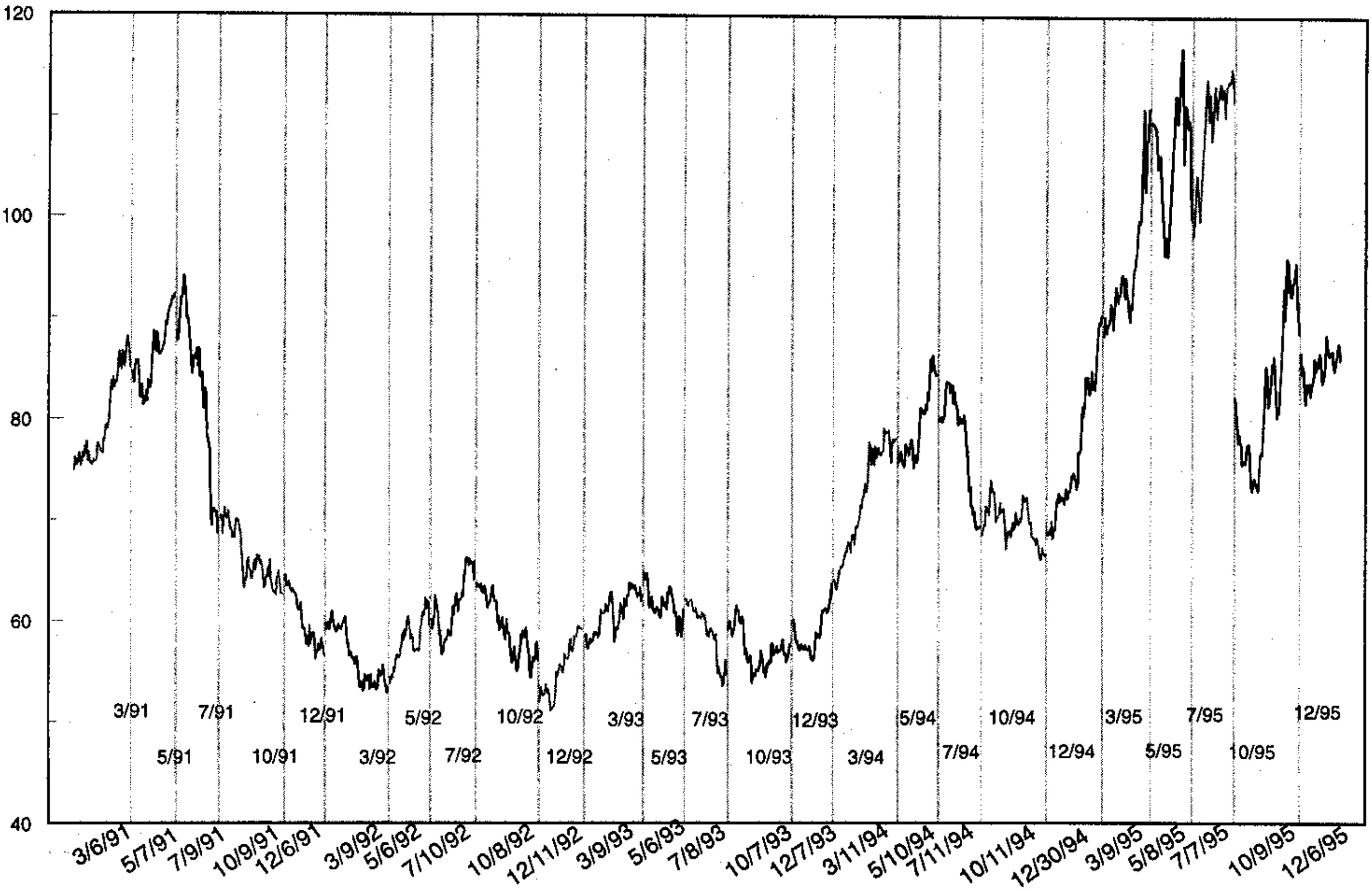

Figure 1 presents the daily closing prices (in cents per pound) for the most active cotton futures contract from year-end 1990 ot year-end 1995. Contracts are separated by verticles lines and are identified by expiration month/year.

FIGURE 2

FUTURES & SYNTHETIC PRICES AT 30-MINUTE INTERVALS

December 1995 contract

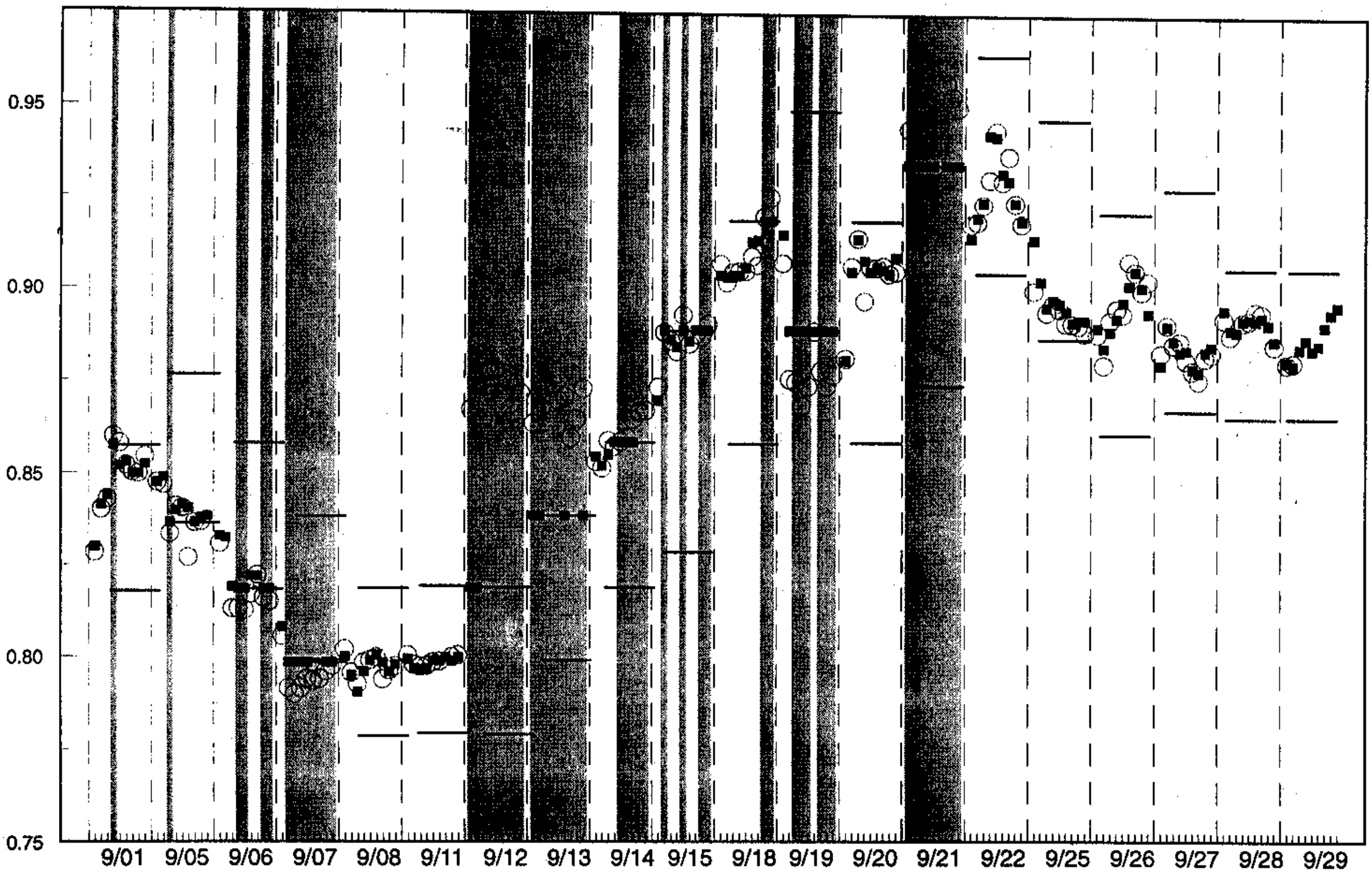

Figure 2 presents the level of futures prices and synthetic future prices (in dollars per pound) for the month of September 1995 for the December 1995 cotton futures contract. There are 9 observations per day, one per half hour from 10:30am to 2:30pm. The horizontal lines each day represent the price limits, the 4-cent or 6-cent band of prices, centered around the previous day's close, in which all transactions must take place. The solid squares represent the levels of the futures prices, and the hollow circles represent the levels of the synthetic futures prices. The vertical shaded areas represent times when the futures were trading at the limit or when the futures were not trading at all and the synthetic futures prices were outside the price limits.

FIGURE 3

ACTUAL FUTURES PRICES & SYNTHETIC FUTURES PRICES

September 1995 for contracts of all tenor

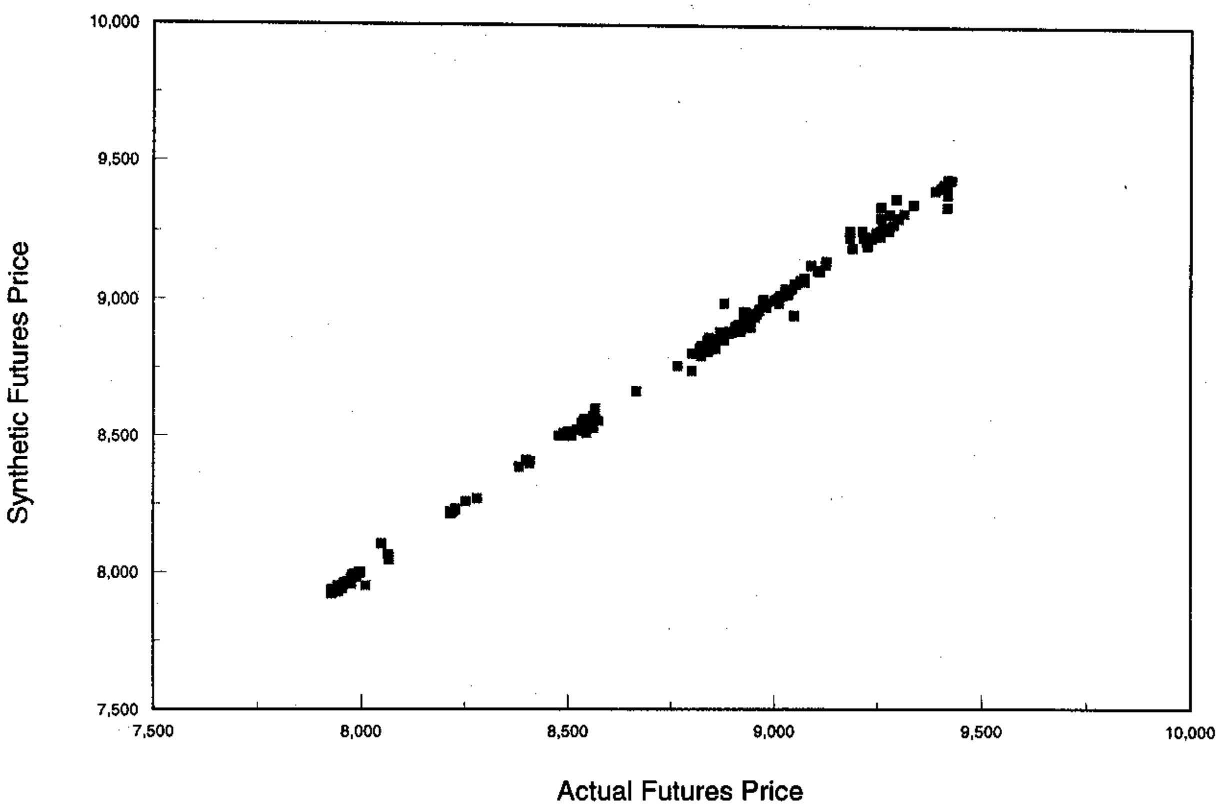

Figure 3 presents the relationship between the actual futures price and the synthetic futures prices (in points per pound) during the month of September 1995 for futures contracts of all tenors. Each synthetic futures trade in September was matched with a futures contract of the same tenor which was reported at the same minute. If more than one futures or synthetic futures traded were reported at the same minute, the equally weighted average futures or synthetic futures was used.

FIGURE 4

CHANGES IN ACTUAL VERSUS SYNTHETIC FUTURES PRICES
September 1995 for December 1995 contract

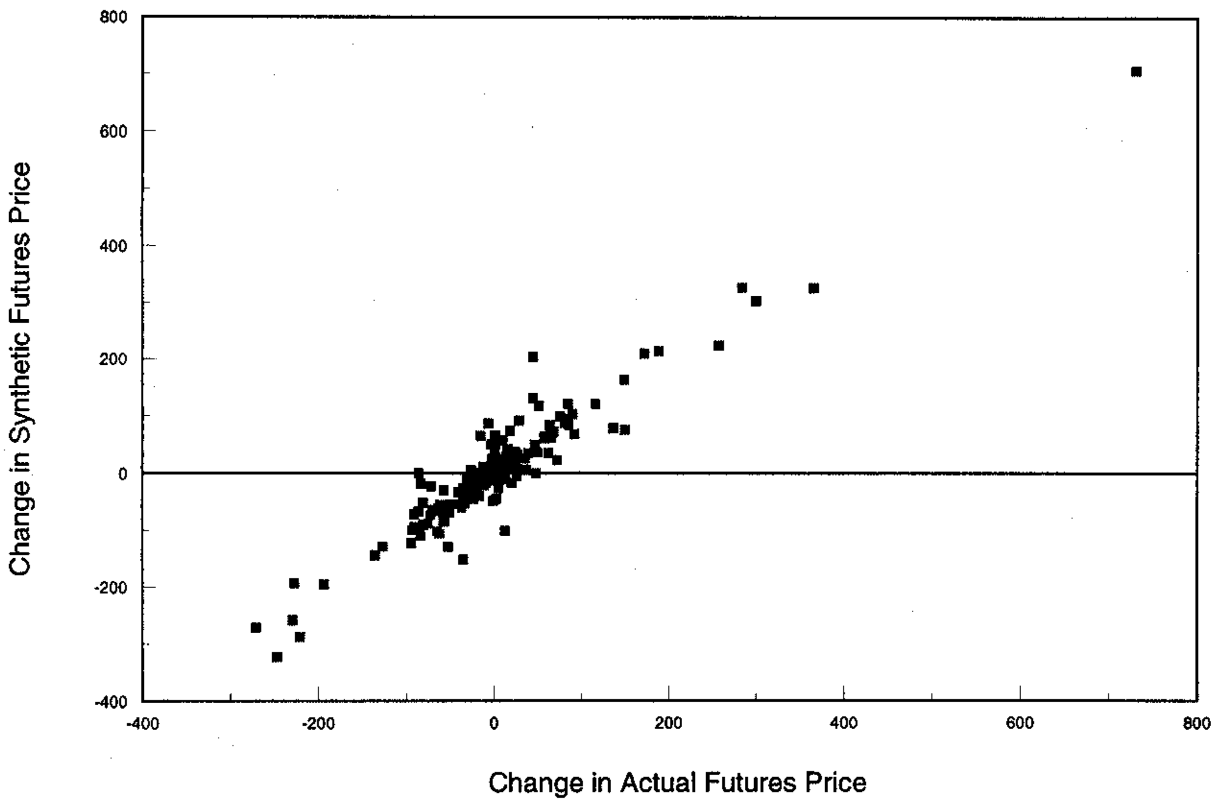

Figure 4 presents the relationship between changes in futures prices and synthetic futures prices (in points per pound), using the data used in Figure 3, but for the December 1995 contract only.

FIGURE 5

VOLUME OF FUTURES TRADES VERSUS FRACTION OF DAY IN LIMIT

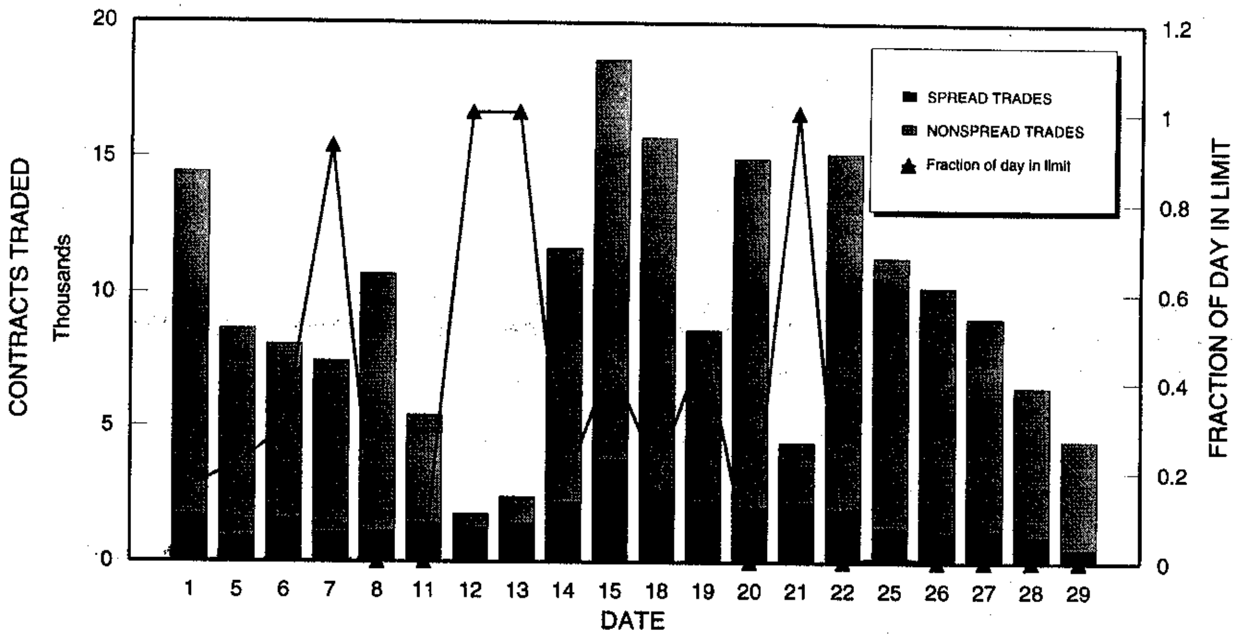

Figure 5 presents the daily total volume of futures contracts for the month of September 1995 (bars and left axis) as well as the fraction of day that the December 1995 contract was in limit. The total futures volume is broken into two catagories -- spread trades and non-spread trades. The graph highlights the relationship that few futures trade on days that are in limit all day (such September 12, 13 and 21) relative to days that are not in limit at all.

FIGURE 6

VOLUME OF OPTIONS TRADES VERSUS FRACTION OF DAY IN LIMIT

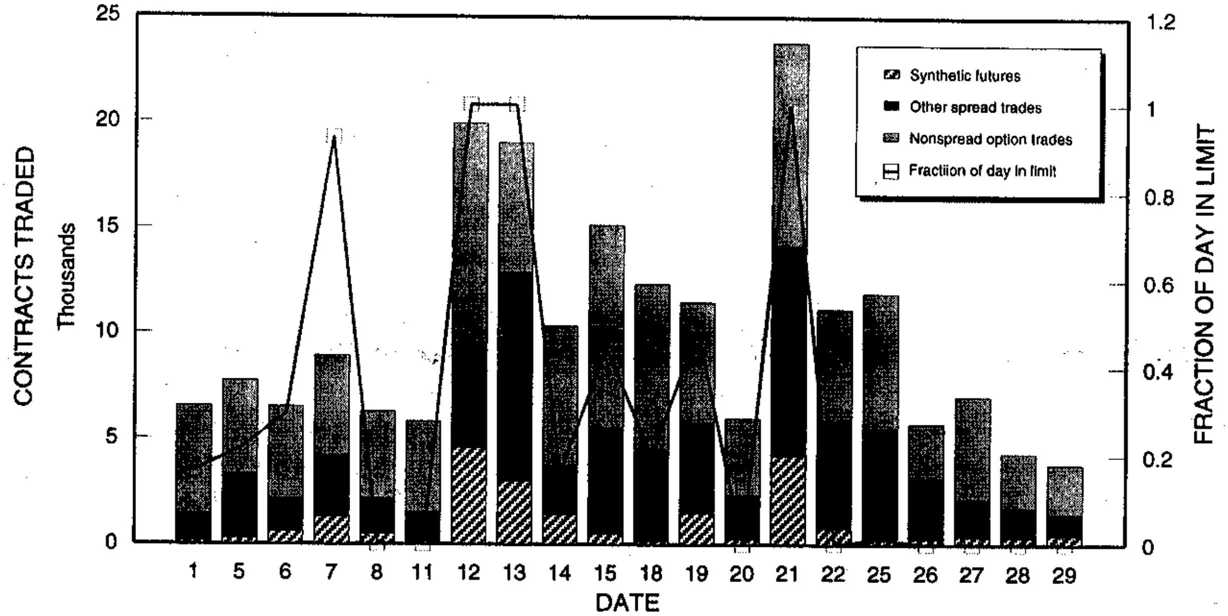

Figure 6 presents the daily total volume of options contracts for the month of September 1995 (bars and left axis) as well as the fraction of day that the December 1995 contract was in limit. The total options volume is broken into three catagories -- synthetic futures trades, other spread trades, and non-spread options trades. The figure highlights the relationship that more options trade on days that are in limit all day (September 11, 12, and 21) than on other days.

FIGURE 7

TOTAL RISK TRADED VERSUS FRACTION OF DAY IN LIMIT

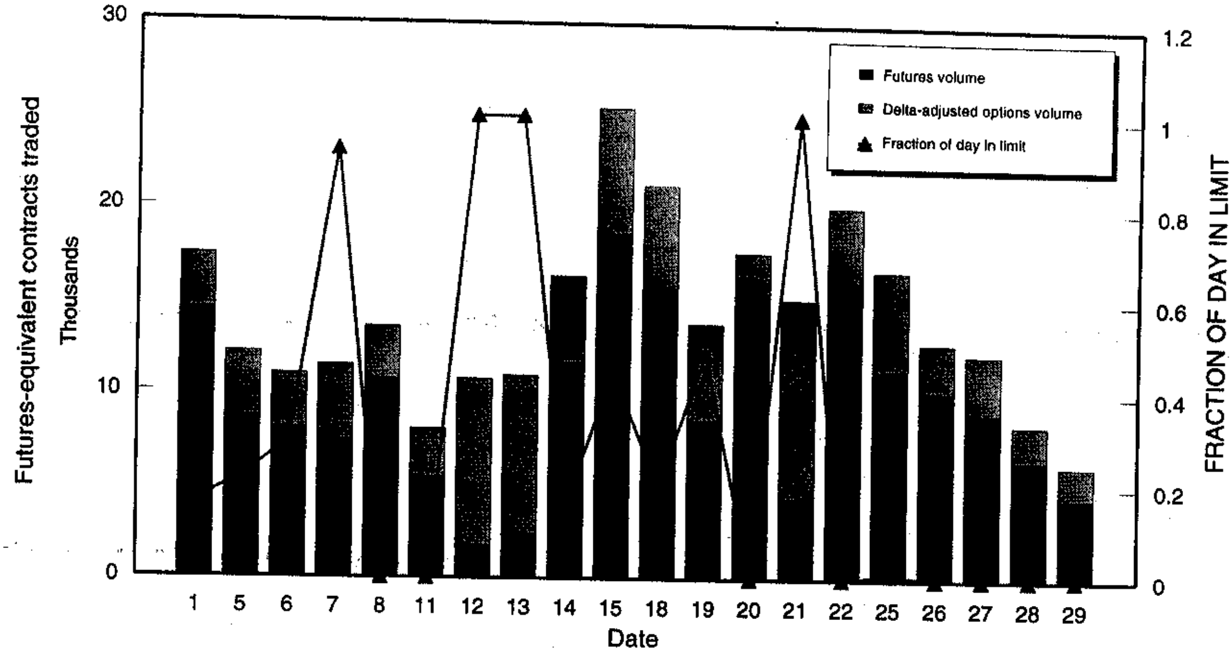

Figure 7 presents the daily total risk traded (defined as the sum of the futures and the delta-weighted options volume) for all contracts traded in September 1995, as well as the fraction of the day in limit for the December 1995 futures contract. The total risk traded is broken into two catagories: the futures volume and the delta-weighted options volume. The analysis indicates that the fraction of day in limit and the total risk traded are not significantly correlated.

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1996

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