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by

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Stress Testing Portfolios to Measure the Risk Faced by Futures Clearinghouses

Roger D. Fuhrman*

Clearinghouses at organized exchanges provide clearing, settlement and risk management systems in supporting exchange traded futures and options. As the exchanges have grown for several decades, questions regarding contract performance and client protection have become more important to market participants. This paper outlines the strategies used by the Board of Trade Clearing Corporation to measure the market risk faced by each clearing member by completing stress tests on portfolios at each firm. These stress tests are part of a multi-tiered system of safeguards that allow the clearinghouse to be the counterparty to every trade on the exchange.

Introduction

Virtually every clearinghouse for an organized exchange operates a mult-tiered system of financial safeguards designed to provide a creditable guarantee of contract performance. At the Board of Trade Clearing Corporation (BOTCC), this system of financial safequards has seven key components.

The first component is ***the guarantee*** itself. Like every other clearinghouse in the world, BOTCC operates a "perfectly matched book." The clearinghouse never assumes an obligation to a clearing member under the exchanges' contracts unless, and until, it has a precisely equal and offsetting claim against another clearing member. Through the operation of the guarantee, every clearinghouse insures that it is never assuming market risk directly. Nevertheless, BOTCC and every clearinghouse does face counter-party credit risk.

The membership admission process is a method for managing this counter-party risk. Through the initial screening process, the clearinghouse seeks to insure that it deals only with the most credit-worthy counterparties.

Despite the quality of BOTCC's admission standards and process, a given member's credit-worthiness may deteriorate over time. This is reviewed frequently by the clearinghouse in its' ***"credit watch" process***. At BOTCC, this includes regular financial reporting requirements. A member on a credit watch may be subject to more frequent financial reporting, closer than normal surveillance, higher than normal margins, and restrictions on the firm's business at the exchange.

The ***variation settlement process*** is another step in the risk management process. This entails marking trades to their current market value, collecting losses, and paying out gains. This is one of the hallmarks of organized futures markets. The variation settlement process ensures that losses are not allowed to accumulate within the clearing system. At BOTCC, prices are marked to market twice each business day, for each firm's current trades and open positions.

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This system allows BOTCC to collect approximately 85% to 90% of the money settlement on a same day basis.

The variation margin substantially reduces the clearinghouse's risk from an adverse price change. However, the clearinghouse must assume some level of risk on pending trades. To cover the risk on member's open positions which are carried overnight, BOTCC has imposed ***original margin, or performance bond requirements***. These margins are designed to cover the potential price change in a given contract with a 95% to 99% level of confidence. The original margin deposits can be paid with a variety of liquid financial assets. The value of the deposits is reduced by an appropriate amount to account for the daily price fluctuations of these assets. This reduction below the market value is called a haircut, and is used to further protect the clearinghouse.

Another line of defense is the ***predefined settlement limits*** of the exchange, which limit trading when prices advance or decline by a set amount.

If all of these lines of defense fail, it is ultimately ***the credit-worthiness of the clearinghouse*** itself which stands behind its guarantee. This is measured by the clearinghouse's own net worth, its ability to raise additional capital (through issuing stock, a clearing fund, or other assessment mechanism) or its capacity to borrow money. It is at this last line of defense that the stress test is used in measuring the clearinghouse's ability to withstand a severe default by one or more of its members. In order to analyze its exposure to each of the clearing members, it is prudent for the clearinghouse to run stress tests on each member's positions. These stress tests are designed to cover catastrophic events in the markets that may occur. These situations are highly unusual, but not impossible. Therefore it is difficult to know what are reasonable assumptions in these unlikely conditions.

Value at Risk and Stress Testing

Managers in firms that face market risk usually utilize two components of risk management. These are value at risk, or VAR, and stress testing. These risk management techniques have significant differences, and are used as complementary methods for analyzing the market risk a firm faces.

Value at Risk is based on a probability distribution, which relates magnitudes of all possible market value changes to their probabilities. VAR methodology is based on recent historical prices. Therefore, VAR will miss the most severe market movements. The margining system used by BOTCC is a similar type of calculation in that it sets margins that cover the price risk during normal business days.

Stress tests, on the other hand, are made to cover market events outside of these normal business days. Some examples of extreme events would include the stock market crash in October, 1987, the European monetary crisis in September, 1992, and the Mexican financial markets in December 1994 and January 1995. A more detailed discussion of the probability of three of these rare, but significant events follows.

Event: Stock Market Crashes of the Late 1980's

Hypothesis: stock returns are lognormally distributed with annualized volatility of 20%.

October 19, 1987:

S&P 500 down 29%
$\log(1-.29)/(.20/252^{1/2}) = -27$ standard deviations

probability = 10^{-160} (impossible)

Therefore from the data presented, if lognormal is the correct distribution, with a standard deviation of 20% per year, then the 1987 crash could not happen.

October 13, 1989:

S&P 500 down 6%
$\log (1-.0612)/(.20/252^{1/2}) = -5$ standard deviation

Probability = .00000027 (1 day in 14,756 years)

April 14, 1912:

Titanic Sinks

"We are perfectly satisfied that the Titanic is unsinkable. We are absolutely certain that she is able to withstand any damage. She may be down by the head, but would float indefinitely in that condition."

The Titanic is described as unsinkable owing to the strength with which she is constructed and to the fact that she is fitted with fifteen transverse water-tight bulkheads. This means that the vessel is divided into fifteen separate compartments, each of which can be rendered water-tight at a moment's notice by the closing of the water-tight doors.

Any two of these compartments can be simultaneously flooded without in any way imperilling the safety of the ship. . .

From a press release by International Mercantile Marine, 4/16/1912.

Stress Testing Portfolios at the Board of Trade Clearing Corporation

The purpose of stress tests is to show the market risk associated with the worst-case scenario faced by the Clearing Corporation due to a member default. Stress tests of each

member's proprietary and customer positions are completed daily to evaluate the potential exposure to each firm. Because of the daily testing, the most recent portfolio is evaluated, thus taking into account any changes of the open interest of different futures and options over time.

Outstanding Contracts

The following table shows open interest for the 12 largest futures and options contracts at the Chicago Board of Trade as of March 31, 1997.

	Futures	Options	Total
U.S. Bond	468,713	652,763	1,121,476
Corn	376,946	416,084	793,030
10 Yr Note	331,916	293,083	624,999
Soybeans	188,449	292,800	481,249
5 Yr Note	223,696	81,502	305,198
Wheat	84,405	126,795	211,200
Soybean Meal	107,197	56,493	163,690
Soybean Oil	97,302	26,640	123,942
2 Yr Note	22,111	0	22,111
30-Day Fed Funds	35,805	---	35,805
Municipal Bond Index	15,413	17,375	32,788
Oats	13,018	3,358	16,376

Frequency of Occurrence

The different levels of the stress test are price moves that replicate probability levels of price changes for each contract. The frequency distribution of price changes looks very similar to a normal distribution, in that it is symmetrical. However, these price changes show a higher concentration of occurrences near zero. This peaked curve is also known as a leptokurtic curve. The distribution also shows a higher concentration of large price moves in the tails than a normal curve would predict.

Method 1: Worst Case Scenario Based on Historical Price Moves

In order to define a rational limit to abnormal market conditions, historical studies were conducted to determine the extreme move in each futures market over the last 35 years. The maximum price move was the greatest number of consecutive days that prices moved the daily limit in the same direction. The contracts studied were Wheat, Corn, Oats, Soybeans, U.S. Bonds, and 10 Year Notes. All contracts' largest potential moves were determined under the

following guidelines: financial contracts were changed by the larger of the two standard deviation moves in the Bond and 10 Year Note contract. Agricultural contracts were changed by the largest standard deviation change of the major grains contracts.

Under the following guidelines, maximum moves were determined for each market. In each contract, the change was a series of consecutive limit moves. This is in effect one daily move because, in the event of a default on the first day of the series, the clearinghouse may not have the opportunity to liquidate or offset the positions until the end of the run. In order to most conservatively reflect the risk, the assumption was made that the first locked limit move occurs after the mid-day variation, so as a result the whole value of the first limit move can be considered at risk. The largest observed market price changes are indicated in the table below.

Maximum Historical Moves for Major Contracts

Commodity	Date	Move $/Contract	Move % of Price	St Devs
Wheat	07/30/73 - 08/14/73	$1.50	43.60%	26.55
Corn	06/14/88 - 06/23/88	$0.88 ½	34.10%	**39.18**
Oats	06/20/88 - 06/23/88	$0.80	26.85%	22.14
Soybeans	07/12/73 - 07/25/73	$4.00	54.05%	21.70
US Bond	10/20/87 - 10/21/87	5 29/32	N/A	7.70
10 Yr. Note	10/20/87 - 10/21/87	4 27/32	N/A	**13.32**

For the financial contracts, the maximum price move was in actual dollar values. For the grains and soybean markets, the price moves were taken as a percent of price, and then compared with current prices. This difference is due to the fact that in the grains and soybean markets, price levels have changed substantially over time with inflation. In the financial contracts, however, long-term inflation is not a necessary consideration in determining what the price moves would mean in 1997 dollars.

The standard deviations were determined by evaluating the price changes for the twelve months prior to the maximum price move in each contract. The maximum moves could then be expressed in terms of standard deviations (right column of Table I). The largest agricultural and financial standard deviation is in bold-face. For agricultural futures, the largest deviation was 39.18, found in corn, and for financial contracts, it was 13.32 in the 10-year note. These figures are then used for all agricultural and financial contracts respectively.

The next step was to take these two maximum standard deviations and apply them to all contracts based on current market activity. This was done by taking the last twelve months of price changes, and determining their standard deviations. Then, the two figures, 39.18 and 13.32, were applied to these deviation numbers to generate maximum potential moves. They are shown in the next table.

Maximum Potential Moves for all Agricultural and Financial Futures				
Commodity	STD over Past Yr.	Max STD	Potential Move:	per contract:
Wheat	$288.65	39.18	$11,310	$2.26
Corn	$117.66	39.18	$4,610	$0.92
Oats	$117.26	39.18	$4,595	$0.92
Soybeans	$303.83	39.18	$11,905	$2.38
Soy Meal	$194.90	39.18	$7,637	$76.37
Soy Oil	$209.98	39.18	$8,228	$13.71
US Bond	$606.77	13.32	$8,083	8 3/32 pts
10 Yr. Note	$403.96	13.32	$5,381	5 12/32 pts
5 Yr. Note	$277.98	13.32	$3,703	3 23/32 pts
2 Yr. Note	$257.07	13.32	$3,425	3 14/32 pts
Fed Funds	$92.63	13.32	$1,234	29.61 pts
Municipal Bond	$581.16	13.32	$7,742	7 24/32 pts

Method 2: Worst Case Scenario Based on Market Concentration

In each of the limit move days, there was more than an incidental amount of trading volume. For this reason, the assumption was made that BOTCC would be able to liquidate a certain number of open positions in the event of a default by one of the largest firms during a locked limit move. However, it is unlikely that BOTCC would be able to get out of all the positions on the first day. For this reason, BOTCC undertook a study to determine, based on actual maximum moves for the major commodities, how much could reasonably be expected to be liquidated on each day until positions of the largest firms are fully closed out.

Average volume for the thirty days prior to the maximum move in each major contract was compared to the volume in the first few days of the maximum move. These percentages were then applied to current 30-day averages to generate hypothetical volume figures for the first few days of a maximum move if it were to occur today. Then, two of the largest firms in the financial and agricultural markets, respectively, were used (Called Firms 'Fin' and 'Ag' for the remainder of this paper). Under the assumption that BOTCC could be up to 50% of the volume on those first few days of the maximum move, the time it would take to liquidate all of Firms Fin and Ag's positions could be derived under these assumptions. The results are shown in the following table:

Major Firms' Open Interest vs. Volume Expectations during Limit Moves										
	Wheat		Corn		Soybeans		Bonds		10 Yr.	
	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
Max Moves										
30-Day Ave	5,629		46,701		8,805		347,217		24,813	
Day 1	2,677	48%	74,135	159%	8,381	95%	34,487	10%	9,090	37%
Day 2	713	13%	30,573	65%	6,425	73%	311,180	90%	53,604	216%
Day 3	3,624	64%	64,529	138%	4,787	54%	366,911	106%	47,490	191%
Day 4	8,491	151%	101,940	218%	13,239	150%	323,253	93%	30,687	124%
Day 5	1,889	34%	41,478	89%	7,609	86%	262,409	76%	19,780	80%
Current										
30-Day Ave	21,490		70,307		48,050		337,281		72,136	
Day 1	10,220		111,608		45,734		33,500		26,426	
Day 2	2,722		46,027		35,060		302,275		155,833	
Day 3	13,836		97,146		26,122		356,411		138,059	
Day 4	32,417		153,467		72,243		314,002		89,211	
Day 5	7,212		62,444		41,521		254,899		57,503	
Current * 50%										
Day 1	5,110		55,804		22,867		16,750		13,213	
Day 2	1,361		23,013		17,530		151,137		77,916	
Day 3	6,918		48,573		13,061		178,205		69,029	
Day 4	16,208		76,734		36,122		157,001		44,605	
Day 5	3,606		31,222		20,761		127,450		28,751	
Open Interest										
Major Firms										
Firm Fin							58,903		44,589	
Firm Ag	-2,969		-77,170		-17,360					

Financial contracts: For the Bonds, BOTCC could liquidate Firm Fin's positions in two trading days. The trading rules at the Chicago Board of Trade automatically expand the limits and margins after the first locked limit day. Therefore the largest possible price move before liquidation of the largest firm's positions would include two limit moves (1 normal + 1 variable), which would equal 7 ½ points. Since the price limits in each financial contract, which are standard at three points, do not reflect equivalent probabilities of occurrence, equivalent changes in the Treasury Notes, Fed Funds, and Municipal Bonds were derived by translating the Bonds' price change into standard deviations and applying it to the other financial contracts.

7 ½ pts = 11.28 standard deviations for the Bonds.

10 Yr.:	11.28 standard deviations for the 10 Yr.	=	4 13/32 points
5 Yr.:	11.28 standard deviations for the 5 Yr.	=	2 31/32 points
2 Yr.:	11.28 standard deviations for the 2 Yr.	=	2 18/32 points
30-Day:	11.28 standard deviations for the 30-Day	=	0.79 points
Municipal Bond:	11.28 standard deviations for the Municipal	=	7 3/32 points

Agricultural commodities: In the commodity markets, the corn market was used to determine the hypothetical loss scenario. Using the information from the table above, three limit moves (1 normal limit + 2 variable limits) was deemed a realistic assessment. Although Firm Ag's open interest in corn was slightly less than the two-day assumption, a conservative choice was made by using a three-day assumption for corn. This three day assumption could then be applied for all the major grains, under the assumption that limit moves in the grains, unlike in the financial contracts, reflect equivalent probabilities of occurrence.

Thus, the following hypothetical price changes were derived:

Hypothetical Maximum Price Moves

	Dollars	Per Contract Specifications
Wheat:	$4,000	$0.80 per bu.
Corn:	$2,400	$0.48 per bu.
Oats:	$2,000	$0.40 per bu.
Soybeans:	$6,000	$1.20 per bu.
Soy Meal:	$4,000	$40 per ton
Soy Oil:	$2,400	$0.04 per pound
US Bond	$7,500	7 ½ pts.
10 Yr. Note	$4,414	4 13/32 pts.
5 Yr. Note	$2,972	2 31/32 pts.
2 Yr. Note	$2,577	2 18/32 pts.
Fed Funds	$786	19 pts.
Municipal Bond	$7,100	7 3/32 pts.

Method 3: Worst Case Scenario Through Statistical Analysis

A ten year study of the price changes was the third method used to determine the appropriate stress testing intervals. This study is completed by the Economic Research Department at the Board of Trade Clearing Corporation each year. The results are shown in the following table.

The most recent ten year study shows the 99th percentile of expected price changes in the third column. For example, in the US Bond futures, a price move greater than $1,589 would be expected to occur only once in 100 observations. The next column shows the smaller of the largest price movement that was observed, or the current daily price limit. In the US Bond futures, for example, the price moved the daily limit of $3,000. The next column shows that this $3,000 price change occurred twice during the ten year period. The last column shows that this limit move occurred 0.08% of the time (2/2528). The 5 Yr. Notes, 2 Yr. Notes, and 30 day Fed Funds have all traded for less than 10 years, and have never changed by the daily price limit.

History of Price Activity

Actively Traded Contracts from 1987 to 1996

Futures	Number of Observations	99th Percentile	Daily Price Limit or Maximum*	# of Days	% of Days
US Bond	2530	$1,589	$3,000(L)	2	0.08%
Corn	2530	$458	$600(L)	22	0.87%
10 Yr. Note	2530	$1,088	$3,000(L)	1	0.04%
Soybeans	2530	$1,137	$1,500(L)	39	1.54%
5 Yr. Note	1923	$700	$1,734	1	0.05%
Wheat	2530	$668	$1,000(L)	8	0.32%
Soy Meal	2530	$720	$1,000(L)	33	1.31%
Soy Oil	2530	$489	$600(L)	41	1.62%
2 Yr. Note	1651	$602	$1,500	1	0.07%
30 Day Fed Funds	2086	$365	$1,333	1	0.05%
Municipal Bond	2530	$1,373	$3,000(L)	3	0.08%
Oats	2530	$441	$500(L)	48	1.90%

* Lesser of the current limit (L) or the absolute largest price move of the last ten years.

The worst case scenario is a price movement that would be substantially greater than the original margin that is collected on each contract. This margin is roughly three daily standard deviations in any given market, or at the 99th percentile of recent price moves. The margin levels are evaluated every month, based on the most recent six months of price changes.

The stress test is used to cover the potential loss when prices move by a more extreme amount. For this reason, the stress test intervals are determined by the ten year study.

The following table shows two levels of the daily price changes (in dollars) that are used in the stress test calculations.

Stress Testing Levels Based on Ten Year Statistical Analysis		
	99th %	Extreme
U.S. Bond	$1,589	$4,500
Corn	458	900
10 Yr. Note	1,088	4,500
Soybeans	1,137	2,250
5 Yr. Note	700	1,734
Wheat	668	1,500
Soybean Meal	720	1,500
Soybean Oil	491	900
2 Yr. Note	602	1,500
30-Day Fed Funds	365	1,333
Municipal Bond	1,373	4,500
Oats	441	750

The first level is the 99th percentile of the ten year price history in each market. This level is often similar to the original margin interval. The extreme level is the largest observation that occurred over the ten year period, unless the largest observed price move was a limit move. In that case, the expanded limit, or 150% of the normal limit, is used in the stress test. In general, the extreme level indicates price movements that could occur on any given day. This level is used in daily stress tests at the BOTCC.

Summary

The following table summarizes the results of the three methods used to determine appropriate stress test levels. The third method, which is a study of the previous ten year history, is recalculated on an annual basis.

The BOTCC uses the stress test intervals to calculate the gain or loss in each clearing members' portfolios should these price changes occur. The change in the portfolio values are determined by changing the market prices both higher and lower in all markets. These calculations are done for proprietary and customer positions at each firm. This allows the Clearing Corporation to evaluate the potential risk of each member, relative to the margins on deposit and capital at the firm.

The stress tests are also used as a method of determining the appropriate level of capital adequacy for the BOTCC. This is one method of determining the credit-worthiness of the clearinghouse which stands behind the guarantee.

The following table summarizes the results from three methods of determining stress test levels.

	Historical Standard Deviations	Market Concentration	Ten Year Statistical Analysis
U.S. Bond	$8083	$7500	$4500
Corn	4610	2400	900
10 Yr. Note	5381	4414	4500
Soybeans	11905	6000	2250
5 Yr. Note	3703	2972	1188
Wheat	11310	4000	1500
Soybean Meal	7637	4000	1500
Soybean Oil	8228	2400	900
2 Yr. Note	3425	2577	1500
30-Day Fed Funds	1234	786	1333
Municipal Bond	7742	7100	4500
Oats	4595	2000	750

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