Price Discovery during Periods of Stress: Barings, the Kobe Quake and the Nikkei Futures Market*

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Abstract

This paper examines price discovery of Nikkei stock-index futures both on the Osaka Securities Exchange (OSE) and the Singapore International Monetary Exchange (SIMEX), around the Kobe earthquake in January 1995, and the collapse of Barings bank six weeks later.

First, we examine the effect of a shock to the economy on a securities market. We study individual variables and conclude that the above-mentioned events did have a large impact. Volume and volatility rise significantly after both events. Interestingly, the earthquake does not have a large impact on the bid-ask spread on SIMEX, while Barings' collapse does seem to have an effect. An interesting aspect of this paper is the fact that we investigate a financial product that is traded simultaneously on two markets. Prices on SIMEX are slightly higher throughout the sample, indicating an impact of Leeson's massive purchases on SIMEX, as well as a perceived absence of systemic risk in the aftermath of Barings' failure.

Second, we examine Leeson's trading strategy more closely. We find evidence months before the actual collapse, that Leeson could be described as a 'doubler.' By continuously doubling his position, he tried to trade his way out of the mountain of losses. If you do recognize such a trader, you could take him out of the market sooner, limiting systemic risk. An important aspect of doublers is that their trading strategy produces normally distributed returns with a high mean for an extended period of time, followed by a very bad event. Among other things, this has important consequences for the effectiveness of Value-at-Risk controls.

* We would like to thank the Osaka Securities Exchange, Mr. Naoto Watari in particular, and the Singapore International Monetary Exchange. Also, we would like to thank the Institute for Monetary and Economic Studies of the Bank of Japan.

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1 Introduction

This paper examines the impact of the Kobe earthquake of 17 January 1995, and the collapse of Barings bank on February 27th on trading activity in Nikkei stock-index futures both on the Osaka Securities Exchange (OSE) and the Singapore International Monetary Exchange (SIMEX). These two events sent shockwaves through international financial markets, and there were fears that the Barings debacle would have serious systemic consequences.

The market for Nikkei futures is interesting in light of these events, because the Nikkei index is the main indicator of Japanese stock market sentiment. Moreover, losses on the Nikkei futures market were the main cause of the Barings collapse. The job of Barings' chief derivatives trader in Singapore, Nicholas Leeson, was to arbitrage between the OSE and SIMEX and try to capitalize on small price differences between the futures contracts. In reality, however, he was taking massive long positions in Nikkei futures, financing SIMEX' margin requirements by selling options and borrowing huge amounts of money from Barings' headquarters in London. By the end of February, the losses had become too large and Barings bank went bankrupt.

The first aim of this paper is to analyse the performance of the Nikkei 225 futures market. One would expect a massive earthquake and the failure of a large market participant to cause a dramatic change in the information asymmetries, liquidity, depth and trading costs. We examine the individual market variables that might have been affected by these two events. The variables considered are the index value itself, its volatility, futures trading liquidity, transaction costs and market depth.

An interesting aspect of this paper is the fact that we investigate a financial product, i.e. futures on the Nikkei 225 stock-index, which is traded simultaneously on the OSE and on SIMEX. Whenever a financial product is traded on two different markets, uncoordinated regulation of those markets could lead to unintended and often unwanted side-effects. A system of strict daily price limits on one of the two exchanges, for example, may lead to shifts in volume and volatility even before the limits are hit (Berkman and Steenbeek, 1998).

Changes in other institutional features may affect the relative trading costs of the two markets in an unintended manner as well. In response to the events mentioned above, the exchanges independently changed margin requirements and imposed trading halts. The situation on the market for futures on the Japanese Nikkei stock-index during the eventful period around the Kobe earthquake and the subsequent collapse of Barings bank, provides us with an excellent opportunity to study the question of whether the action taken by the exchanges was effective.

The second aim of the paper is to examine the trading strategy followed by Nick Leeson more closely. We find evidence months *before* the actual collapse, that Leeson could be described as a 'doubler.' By continuously doubling his position, Leeson tried to trade his way out of the mountain of losses, much like naive players in a casino continuously double their position, because they think it

is impossible that the ball for instance falls on black ten times in a row. We claim that, using the proper information, it is possible to recognize a doubler such as Leeson sooner. If you do recognize such a trader, you could take him out of the market sooner, limiting systemic risk.

This paper is structured as follows. Section 2 provides information on the two events and reviews literature on the effect of information shocks on securities trading. Section 3 describes the institutional background of the Nikkei derivatives market, the exchanges' regulations to limit 'excess' volatility and the specific actions taken by the exchanges in response to the two events. Section 4 presents the data and the methodology, followed by our empirical results in Section 5. Finally, Section 6 concludes.

2 Background

2.1 The Kobe earthquake

In the early morning of January 17th, 1995, an earthquake with a force of 7.2 on the Richter scale shook the Japanese city of Kobe, killing 4,500 people, leaving 15,000 people injured and more than 200,000 homeless. The total economic damage was estimated to be approximately 6.9 trillion yen (about US$70 billion). The Great Hanshin-Awaji Earthquake, as the shock was called, was the most destructive earthquake since the great Kanto-shock in 1923.

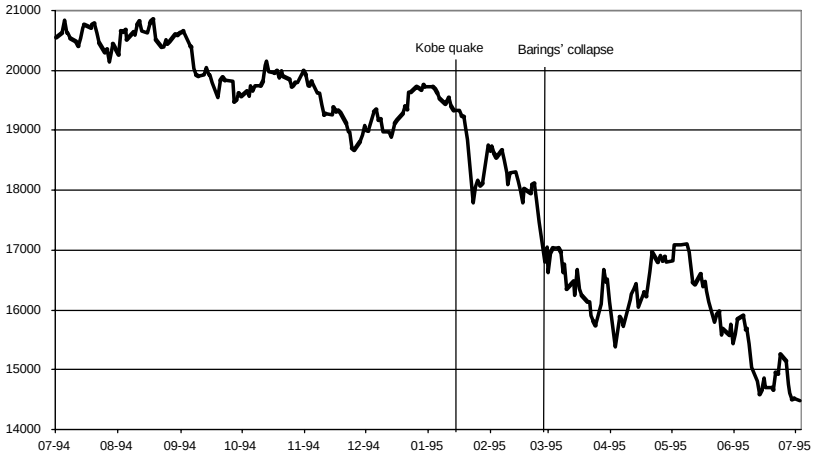
Analysts initially thought that the economic stimulus from reconstruction would offset the immediate disruption to production. As a result, the Nikkei index dropped only slightly in the three days following the quake. However, after three days it became clear that government action would be limited and sentiment changed dramatically. As a result, the Nikkei index dropped 1,055 points on Monday, January 23rd. Figure 1 shows the Nikkei index over our total sample period from 1 July 1994 until 1 July 1995.

2.2 The Barings collapse

On February 23rd, 1995, the Singapore office of Barings bank was not able to meet its margin requirements on futures positions at the Singapore International Monetary Exchange (SIMEX). On that day, Barings owed more than US$1 billion on financial futures contracts traded through its Singapore office. The loss-making transactions were made by Nicholas Leeson, who was the chief derivatives trader in Barings' Singapore office. The majority of the futures contracts were based on the Japanese Nikkei 225 stock index. These Nikkei futures are traded on the Osaka Securities Exchange (OSE) as well as on SIMEX, and Leeson's main assignment was arbitrage trading. This arbitraging involves buying futures contracts on one market and simultaneously selling them on another, exploiting slight price differences. Profits are small, and therefore trading volumes tend to be large. Still, the risks are low, because

every long position on one exchange is offset by a short position on the other.

Figure 1: The Nikkei index



Source: Datastream

What really brought down Barings bank were large unauthorized speculative positions. The largest part of Leeson's losses came from a massive long position in Nikkei futures. Secondly, he had a large short position in futures on Japanese Government Bonds (JGB's), on which he ran large losses as well, because the market was rising. Thirdly, Leeson built a position of short straddles[1] in late 1994 to finance the margin on his futures positions. This straddle would have been profitable as long as the Nikkei index remained within a band of ¥18,500 to ¥21,000. Leeson tried single-handedly to support the market by buying a large amount of Nikkei futures, expanding his long position in Nikkei futures to over 61,000 March contracts on February 23rd, or 60% of total open interest on SIMEX. When the Nikkei dropped below ¥18,000 on February 23rd, Barings was not able to meet SIMEX' margin calls. On Monday February 27th, Barings formally collapsed.

Systemic risk issues

Barings' collapse did not initiate a collapse in securities prices or widespread bankruptcies, despite grim predictions. Apparently, confidence in the banking industry was not affected strongly. It was evident that one man had caused the

[1] A short straddle is a combination of a short call and a short put with the same exercise price.

problems at Barings, and it was believed that this could not happen easily at other banks.[2] Also, feared problems in the interbank market didn't occur, because Barings was relatively small and shortly after its demise it was taken over by the Dutch ING group which took over all of Barings' liabilities. The contribution of the event to the international financial system is that it put a strong focus on internal risk management systems, where many systemic problems originate. Also, the damage to SIMEX' reputation appeared to have been limited. Trading volumes in all products remained high.

A factor that kept the Nikkei index volatile after February 27th, was the fact that fifteen Japanese banks had made a total of 67.7 billion Yen (US$720m) in loans to Barings Securities. Most of these loans were used to cover the cost of Leeson's margin requirements, because both the OSE and SIMEX require margin payments to be paid in yen. The already fragile Japanese financial system comprises a relatively large part of the Nikkei index (approximately 20%) and uncertainty about the extent to which the new losses would be recovered, had a large impact on the index.

2.3 Information shocks and price discovery: review of literature

The impact of new information on price formation has been subject of many academic studies. Generally, the literature suggests that an information shock is expected to induce an increase in volatility, at least temporarily. Higher volatility would, in turn, lead to higher trading volume, wider bid-ask spreads and decreasing depth.

Volatility and trading volume

Widespread concern over volatility in securities markets has stimulated research into the process by which information is impounded in securities prices. One important question is whether investors react in a rational way to unanticipated announcements. Under the certain information hypothesis, Brown et al. (1988) propose that volatility will increase following the announcement of any major unanticipated event as the market responds to the incomplete information concerning the event. A number of papers have developed market microstructure models that incorporate the different responses of informed and liquidity traders to unanticipated announcements. Kim and Verrecchia (1991) conclude that post-announcement volume is a function of the absolute price change accompanying the announcement and the extent to which the precision of information changes across traders who are heterogeneously informed. Foster and Viswanathan (1993) construct a model that relates unexpected news to higher trading volume and volatility as a result of trading between informed and liquidity traders.

[2] However, as became clear in the Summer of 1995, a single bond trader at the New York office of Daiwa bank had accumulated losses of $1 billion over a period of 11 years.

Transaction costs

Uncertainty in the market generally leads to higher transaction costs (wider bid-ask spreads) as well. Grossman and Miller (1988) discuss the issue in terms of the supply of immediacy. The risk of delaying a trade creates a demand for immediacy, and the transference of risk to the market maker (or limit order provider) will be reflected in the bid-ask spread. Transaction costs are strongly linked to liquidity and hence volatility shocks.

Information shocks and the trading system

An important difference between the OSE and SIMEX is the trading system. As explained in more detail below, the OSE employs a computerized trading system, while SIMEX relies on an open-outcry system. In periods of low information intensity, trading volume is low and transactions are infrequent. As a result, information on the last trade is fairly old so that the limit order book information of the electronic system is more updated and, hence, an important indicator of market developments. At the same time, traders are relatively inactive so that observation of their behavior on the floor does not reveal much about their intentions and, thus, does not permit reliable predictions of their activities over the next period. Finally, there is not much to be gained from conversation among traders since new information to be evaluated is lacking. Hence, in a period of low information intensity, the order book information of the electronic system appears to offer more signals for predicting market developments than observation of traders on the floor.

In periods with much new information the danger of adverse selection increases. As the identity of the trading partner is unknown in an anonymous electronic system, there is little protection against adverse selection. Traders may refuse trading, reduce their (volume of) limit orders in the order book, or shorten the average time span for the display of an order in the order book. This will reduce the information content of the order book. In a floor system, traders build up a reputation for fair trading. Every trader knows the other traders so that information trading is considered unfair although not ruled out. But there is some sanctioning power of traders creating a barrier to adverse selection (Pagano and Röell, 1993). Thebarrier becomes more important in periods of high information intensity. Furthermore, observation of other traders becomes more informative. If, for example, the same trader buys several times, then this indicates that he may act on private information or that outsiders place large buy orders. In addition, body language of active traders is likely to reveal something about their next trades although they may want to camouflage their intentions.

Massimb and Phelps (1994, p46) provide another reason for the relative higher efficiency of an open-outcry system in a high volatility period. Calling a situation where there is great uncertainty about the equilibrium price a ‘fast market,’ they write: ‘Open outcry handles fast markets surprisingly well because a trader can change a bid or offer very quickly. A trader simply changes a hand signal and makes a brief verbal announcement, and his previous bid or offer is

automatically and implicitly cancelled.' They claim the risk for electronic matching systems in fast markets is that the response time (elapsed time between the trader pressing an action key and the system confirming or rejecting the action on the trader's screen) degrades as message traffic increases. Martens and Steenbeek (1997) find evidence for the prediction that the relative importance of SIMEX increases when the market is volatile.

Doubling

Information from Leeson (1996) and others indicates that Leeson can be described as a 'doubler.' By continuously doubling his position, Leeson tried to trade his way out of the mountain of losses, much like naive players in a casino continuously double their position, because they think it is impossible that the ball for instance falls on black ten times in a row. If you could recognize such a trader, you could take him out of the market sooner, limiting systemic risk. A quote from Leeson may illustrate our point:

'I felt no elation at this success. I was determined to win back the losses. And as the spring wore on, I traded harder and harder, risking more and more. I was well down, but increasingly sure that my doubling up and doubling up would pay off ... I redoubled my exposure. The risk was that the market could crumble down, but on this occasion it carried on upwards ... As the market soared in July [1993] my position translated from a £ 6 million loss back into glorious profit.

I was so happy that night I didn't think I'd ever go through that kind of tension again. I'd pulled back a large position simply by holding my nerve ... but first thing on Monday morning I found that I had to use the 88888 account again ... it became an addiction.' (Leeson, 1996, pp.63-64).

3 Institutional background

Derivatives based on the Nikkei 225 stock-index are traded on a number of markets. The most important market is the Osaka Securities Exchange, followed by SIMEX in Singapore. Contracts are traded in similar design, but there are a number of differences.

3.1 The Osaka Securities Exchange

The OSE employs a continuous double auction trading system where buy and sell orders directly interact with each other through an order book. The order book is managed by so-called *nakadachi* members, who solely function as middlemen in transactions between regular members. Nakadachi cannot trade for their own account, nor can they accept orders from the public.[3] A special feature of the OSE trading system is that trading takes place in two daily sessions. The morning

[3] On the Tokyo Stock Exchange, where a similar system is in use, the equivalent intermediary is called 'saitori.'

session (*goba*) lasts from 9:00 until 11:00 hours and an afternoon session (*zenba*) from 12:30 until 15:00 hours. During these trading hours two types of auction method are used. Each session is opened by a batched clearing process known as *itayose* and followed by a continuous two-sided trading process called *zaraba*. Itayose trading is performed by batching together all orders submitted prior to the opening and determining the corresponding market clearing price. Once the opening price is established, the zaraba method is used to determine transaction prices on a continuous basis during the remainder of the session. Generally, more than 20% of daily volume is realized in the two itayose transactions. The marginal unexecuted orders remaining in the nakadachi's order book determine the bid and ask prices and the corresponding quantities. If two orders can be matched, then the nakadachi member chooses as matching orders those with the best prices. If there are a number of identical best bids or asks the trade is assigned according to the time of entering the system, the first quote getting the trade. Large orders exceeding the limit order of the quote will be split up over more quotes according to price and time of entering the system. Information on transaction prices and volumes is published instantaneously in the electronic system. A quote is valid until it is explicitly withdrawn from the system.

3.2 The Singapore International Monetary Exchange

SIMEX uses a floor trading system in which dealers trade continuously through open-outcry. Like in Osaka, Nikkei futures are traded in two separate sessions, but the total trading day lasts 45 minutes longer: from 9:00 until 11:15 hours and from 12:15 until 15:15 hours.[4] During these hours, traders publicly announce bids and asks. If a trader finds a bid or ask attractive, the trader simply hits the bid or takes the ask. The transaction price is then made public. Quotes are valid as long as 'breath is warm.' A trader can also request a quote, and then may accept the best offer or refuse trading. When there are more traders with the same offer or ask, the buyer or seller can choose with whom to trade. As there is no official market maker, an official order book does not exist. Names of traders are not published by the exchange. This information is available only to the people on the floor. Once a trade is executed, price information is immediately communicated to the pit observers, who report the transaction over a worldwide electronic communication system. Volume information is not registered simultaneously on SIMEX: traders are required to report transaction size within 30 minutes after the transaction is done (SIMEX, 1995). When trading is hectic, market makers will be less willing to leave their spot on the floor frequently, so the lag between the actual transaction and its report to the floor clerks is likely to be longer.

[4] We follow Japanese time throughout the paper. In reality, Singapore is one hour behind Tokyo time.

3.3 Institutional differences and transaction costs

One of the obvious differences between the two trading systems is the limit order book. At OSE traders have insight into an anonymous limit order book, while at SIMEX no official limit order book exists, but names and behavior of other traders can be observed on the floor. Another major difference is the execution of orders. At OSE a large order can be matched in the electronic system with several orders of the limit order book at different prices. On the other hand, at SIMEX usually the number of contracts for which a quote is valid is fairly high, so that an order is executed at one price only. The main institutional differences are summarized in Table 1.

Table 1 : Nikkei futures: Differences OSE and SIMEX*

	OSE	SIMEX
Contract Unit	1000 times index	500 times index
Minimum fluctuation	¥10	¥5
Daily price limit	about 5%	5% and 10% for 15 minutes
Customers margin	20% (5% cash)	10%
Members' margin	15% (2% cash)	10%
Commission costs	0.080 (trading value ¥1bln.)	0.030 (trading value ¥1bln.)
Trading system	auction	open outcry
Morning session	09:00 - 11:00	09:00 - 11:15**
Afternoon session	12.30 - 15:00	12:15 - 15:15**

* The situation before the Kobe earthquake. Source: OSE (1998) and SIMEX (1998)

** Japanese time

Although a future that is bought in Osaka cannot be sold in Singapore and vice versa, arbitrage between SIMEX and the OSE effectively reduces price differences. Whether an order is executed at a better price in one or the other system, depends on bid-ask spreads and price sensitivity to order volume in both systems. If the spread is lower in the electronic system, but its price sensitivity to order size is higher, then small orders are executed at a better price in the electronic system whereas large orders obtain a better price in the floor system. Therefore, it is often argued that large investors get a better deal in dealer markets than in auction markets (e.g. Pagano and Röell, 1992; De Jong, Nijman and Röell, 1995).

Madhavan (1992) reaches a similar conclusion in his theoretical approach. For

a continuous dealer system and a continuous auction system, with the latter not being anonymous, price competition between dealers eliminates the 'wedge' between the transaction price and the expected value of the asset. Strategic behavior in auction markets, however, distorts prices and thus induces inefficiency. If dealers can impose sufficient sanctions so that traders reveal their private information in trading, then a separating equilibrium may be obtained. In an anonymous market a pooling equilibrium is obtained. Hence the adverse selection problem is allegedly weaker on the floor leading to lower bid-ask spreads and higher trading volume. The latter implies that prices are based on a larger set of information, making adverse selection even more unlikely (Glosten and Milgrom, 1985; Stoll, 1989). On the other hand, risk-averse traders can put very small orders at various prices into the book to protect themselves against adverse selection whereas on the floor quotes are valid for larger order sizes (Glosten, 1994). This allows for a smaller bid-ask spread in the limit order book so that small orders would obtain a better price in the electronic system and larger orders would obtain a better price on the floor.

Various studies have looked into total transaction costs of Nikkei futures trading. Steenbeek (1996) finds that, although the explicit transaction costs are much higher in Osaka (see Table 1), total transaction costs are still lower. Should regulation of futures trading be tightened further, however, SIMEX could well become the cheapest market to trade Nikkei futures. Fremault and Bacha (1996) estimate transaction costs over a number of years and conclude that transaction costs on the OSE were generally lower, although in certain time intervals SIMEX appeared to be cheaper. Fremault and Sandman (1996) study liquidity and efficiency on the Nikkei futures market during June, July and August 1993. They find that trades on the OSE are less frequent, but larger in size and that price volatility measured over very short intervals is significantly lower on SIMEX.

3.4 The exchanges' reply to unexpected events

Both exchanges employ trading rules aimed at limiting 'excess' volatility. The OSE used to go very far in restricting trading in Nikkei derivatives. According to Miller (1993, p.7), 'MOF saw index futures as a threat to its policies for discouraging selling—not just short-selling but any selling.' Hence, futures trading on the OSE was regulated strictly from the beginning. All rules seemed to be aimed at reducing the spill-over effects of futures trading to the market for the underlying stocks. One of the rules was the comprehensive system of price limits. First, Nikkei futures are not allowed to trade at a price outside the range of the previous day's closing price plus or minus the daily price limit. This daily limit depends on the futures price level. Besides the system of daily price limits, there is an intraday price limit rule ('speed bump') on the OSE, called 'special-quote' system. Where a similar system on the Tokyo Stock Exchange seems to work satisfactorily (see, for example: Lehmann and Modest, 1994 and Hamao and Hasbrouck, 1995), the special quote system in Osaka was generally considered too strict. In

February 1994, the rules were relaxed considerably. The daily limit was set at about 5%, and the special quote system was triggered far less frequently.

SIMEX employs two circuit breakers which last for only 15 minutes after the price limit has been hit. The first circuit breaker will take effect when prices reach 5% above or below the previous trading day's closing price. Another 5%, or a total of 10%, will spark off the second circuit breaker. Limits do not apply to the last 30 minutes of trading, unless the 15-minute cooling period started just before. There are also no limits for the last day of trading for the contract nearest to expiry (SIMEX, 1995). It is clear that these rules are far less strict than the price limit rules on the OSE. During our sample period, these price limits were not hit.

Specific action in February 1995

Out of fear that Barings would not be able to meet margin calls, SIMEX almost doubled margins two weeks after the Kobe earthquake, on February 3rd. On the day of Barings' collapse, SIMEX more than doubled margins again. The second margin hike was aimed at dampening further trading in an already cautious market. After SIMEX had completed the process of unwinding the Barings position, margins were narrowed, although not to their level of before February 2nd.

On the OSE, on the other hand, no strong formal action was taken in reply to the events. As a matter of fact, margin requirements for both futures and options were reduced on February 13th.

4 Data and methodology

4.1 Data

Our sample period covers the period starting from 1 July 1994, which is 6 months before the Kobe earthquake until 1 July 1995, which is 4 months after the bankruptcy of Barings. Both from the OSE and from SIMEX, we received tick data on Nikkei futures. The dataset from the OSE includes information on transaction price and volume. However, the dataset does not include quotes. The dataset from SIMEX contains all trades and quotes on all derivatives contracts traded on the Nikkei index. The dataset does not include volume information. Apart from the tick databases, we use daily data containing information on prices, volume and open interest for both exchanges.

A first look at the data reveals that the Nikkei futures market is very liquid. Table 2 compares daily average trading value of Nikkei futures during four subperiods of our sample. Please note that the size of the OSE contract is twice as large as the SIMEX contract (see Table 1).

Table 2 : Nikkei futures: Average daily trading activity

	number of contracts		number of transactions	
	OSE	SIMEX	OSE	SIMEX
July - October '94	21575	20098	1365	1362
November - earthquake	25728	21196	1081	1292
earthquake - bankruptcy	34345	36547	1697	2007
bankruptcy - July '95	25515	25719	1669	1799

Information on the trading activities of Nick Leeson was collected by studying secondary material such as Leeson (1996) and Gapper and Denton (1997).

4.2 Methodology

In our analysis of the events in the beginning of 1995, we should make a distinction between the earthquake and the Barings failure. Of course, the Kobe earthquake is truly an unexpected information shock. It is more difficult, however, to put an exact date on the impact of the difficulties encountered by Barings. The market knew months before the actual collapse that Barings had built up a very large long position in futures.[5] As SIMEX became suspicious, it doubled margins on February 2nd, thereby increasing the cost of trading significantly. On February 27th, eventually, Barings formally went bankrupt.

We are interested in the impact of the events on a number of variables, and try to find an answer to the question how an exchange should act if a similar situation arises in the future. One of the contributions of this paper to existing literature comes from the fact that our dataset allows us to study the theoretical relationships described in Section 2 by looking at the two markets simultaneously. Leeson was the dominant market player on SIMEX' Nikkei futures market, but his role was limited in Osaka. Therefore we can look at the effect of Leeson's actions on the pricing process in Singapore.

Volatility

As a first proxy of market variability we take the absolute daily returns on SIMEX. However, recent studies show that much information is lost when relying on daily closing prices. If on a trading day the return was zero, but within the day

[5] The Financial Times quotes a US fund manager as saying: 'The futures community has known of this mega position for about the last three months. The position kept getting bigger and bigger and bigger. Every time they tried to sell anything, the market would fall,' in: Lapper, R., 1995, 'The Barings crisis: dealers puzzled over unusual futures strategy—Leeson's trading logic,' *Financial Times*, 1 March 1995.

prices fluctuated heavily, the absolute or squared return (equal to zero) is misleading. Other measures are then needed to capture the information that the trading day was actually quite volatile. This provides a partial explanation for the success of applying daily high and low, daily volume, number of price changes and intraday returns. We follow Andersen and Bollerslev (1998) in taking the sum of absolute intraday returns as the measure for daily volatility. We calculate 16 15-minute absolute returns and add the absolute overnight and lunchbreak returns.

Next, we calculate volatility ratios similar to those in Schwert (1990) and look at changes in relative volatility between the two markets. The first day of our sample serves as the base period. While the first period is held constant, we will move the second 1-day period through time. The volatility ratio is calculated by dividing the average absolute daily return of the second period by that of the base period.

$$VOL* = \sum_{i=1}^{16} |R_i| \tag{1}$$

$$VOL = |R_i| \tag{2}$$

$$\gamma = VOL_{period\,2} \,/\, VOL_{period\,1} \tag{3}$$

where VOL* = daily volatility using absolute intraday returns,
VOL = daily volatility using daily 3pm to 3pm returns,
R_i = return over interval i,
γ = volatility ratio.

The process is repeated by moving period 2 through the dataset by one day, estimating γ until the end of the dataset. Moving the second 1-day period through time enables us to compare future volatility periods relative to a point in time.

Finally, we calculate relative volatility between the OSE and SIMEX, using intraday returns calculated over exactly the same intervals.

$$RELVOL = VOL^{OSE} \,/\, VOL^{SIMEX} \tag{4}$$

where RELVOL = relative volatility on the OSE vs. SIMEX
VOL = volatility measured using Equation 1.

Liquidity

As indicated in Section 4.1, the Nikkei futures market is very liquid. The OSE is the dominant market and regained some market share after it relaxed trading rules in February 1994. Using daily data, we examine to what extent the events changed the relative importance of the two exchanges in terms of trading volume. As Martens and Steenbeek (1997) show, price formation is quicker and more

accurate during hectic periods in SIMEX' open-outcry system, while the OSE's automatic trading system functions better during periods of low volatility. We calculate the relative trading activity during the periods of stress as the total number of transactions during the periods that both markets were open. This way, we avoid the data being influenced by trading halts.

$$RELTR = TR^{OSE} / TR^{SIMEX} \tag{5}$$

where RELTR = relative trading volume on the OSE vs. SIMEX
TR = daily number of transactions.

Depth

We calculate relative open interest, using Equation (6). One would expect the OSE to become more important after the margin increases in Singapore.

$$RELOI = OI^{OSE} / OI^{SIMEX} \tag{6}$$

where RELOI = relative open interest on the OSE vs. SIMEX
TR = open interest at the close of trading.

Transaction costs: the quoted bid-ask spread

An important measure of the efficiency of an exchange is the implicit trading cost, measured by the bid-ask spread. For SIMEX, we measure the daily average quoted bid ask spread for every trading day, based on all quote revisions. These data were not available for the OSE.

Price effects

A final research question we try to answer is to what extent Leeson's trading activities actually influenced prices during the months leading up to Barings' collapse. As indicated above, Leeson's trades were mainly done on SIMEX, where he single-handedly tried to support the Nikkei index by buying futures.[6] The extent to which these activities have led to structural price differences between the OSE and SIMEX, provides us with a direct test of the efficiency of the market.

We directly calculate the mean price difference of the two contracts at every 15 minutes of the trading day, provided that there is an observation on both exchanges. We test the following equation for two periods: three months before Leeson's last day on the job and three months after. The prices are based on the last transaction in a given minute. We also test Equation (8), using the lagged SIMEX price, because purchases by Leeson which lead to a positive price difference will be followed by arbitrage transactions between the OSE and SIMEX.

[6] P. Martin and Financial Times writers, 1995, 'The Barings Collapse: Blunders that bust the bank,' *Financial Times*, 24 March 1995.

$$DIFF_t = P_t^{OSE} - P_t^{SIMEX} \tag{7}$$

$$LAGDIFF_t = P_t^{OSE} - P_{t-1}^{SIMEX} \tag{8}$$

where DIFF = price difference OSE vs. SIMEX
LAGDIFF = price on OSE vs. lagged price on SIMEX
P_t = last price in minute t.

We split the sample up in five periods:

period 1	1/7/94 - 30/11/94	base period
period 2	1/12/94 - 16/1/95	heavy trading by Leeson
period 3	17/1/95 - 23/2/95	between earthquake and Leeson's departure
period 4	23/2/95 - 10/3/95	period of uncertainty until ING takes over all liabilities
period 5	11/3/95 - 1/7/95	stabilization

During period 1, one would not expect a significant price difference, since no major events took place and arbitrage takes care of price differentials instantly. In period 2, Leeson purchased massive amounts of futures on SIMEX, trying to push up prices. His actions may have caused price differentials to be more persistent. During period 3, the market became much more volatile and price differentials may have persisted for a longer period. Leeson stepped up his purchases on SIMEX. Period 4 covers the interval during which SIMEX experienced the largest threat. If traders would have been concerned about the health of the exchange, one would expect them to be prepared to pay a premium to hold Osaka futures. Ito and Lin (1996) find some evidence for an increased systemic threat. Finally, period 5 would be a period of stabilization, returning to a 'normal' market.

Doubling

Finally, we investigate the claim that Leeson could have been characterized as a 'doubler.' If the doubling story is correct, we would expect to see an asymmetric response of SIMEX volume to price changes: prices go down, volume increases, with the increase in volume a function of the number of downticks. However, if prices go up we should not see such a relationship. Of course, we only have aggregate data, but if it is true that Leeson was such a significant player, we should see his trades in the aggregate data. We should realize that many studies have shown a relationship between trading activity and volatility. However, we expect to find a certain level of asymmetry between a falling and a rising market. Formally, we test the following equation:

$$V_d^{SIMEX} = \alpha + \beta \cdot PCHANGE + \varepsilon_d \tag{9}$$

where V_d = daily trading volume on SIMEX
PCHANGE = the logarithmic close-to-close return
P_t = last price in minute t.

Since we will be using daily data, we split the sample into three periods of approximately 75 trading days each. Period 1 covers the interval between July 1st and October 31st 1994, Period 2 between November 1st 1994 and February 23rd 1995, and Period 3 between February 23rd and June 30th 1995. The asymmetry is expected to be strongest in period 2.

5 Empirical results

In this section we present the empirical results. Graphs for the individual variables are given below.

Volatility

Figure 2 plots daily volatility over the total sample period. Not surprisingly, volatility increased dramatically following the earthquake. The jump happened four days after the quake, because the market needed that amount of time to assess its impact. Figure 3 shows the Schwert-ratios based on return volatility on SIMEX. We calculate two ratios: one (γ_1) based on daily 3 p.m. prices and one (γ_2) including intraday information. It is clear that ratio 2 follows a smoother path, but follows the same general path. Figure 4 presents relative volatility between the OSE and SIMEX. Before the earthquake, volatility in Osaka is on average 10% higher than in Singapore. SIMEX volatility increases relative to the OSE after the earthquake until the Barings bankruptcy, despite two SIMEX margin increases and a margin decrease in Osaka.

Figure 2: Daily volatility in SIMEX Nikkei futures

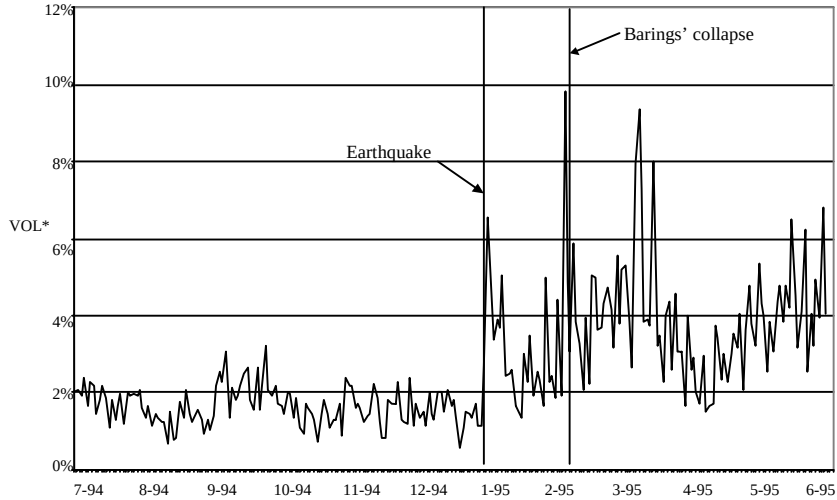


Figure 3: Volatility ratios

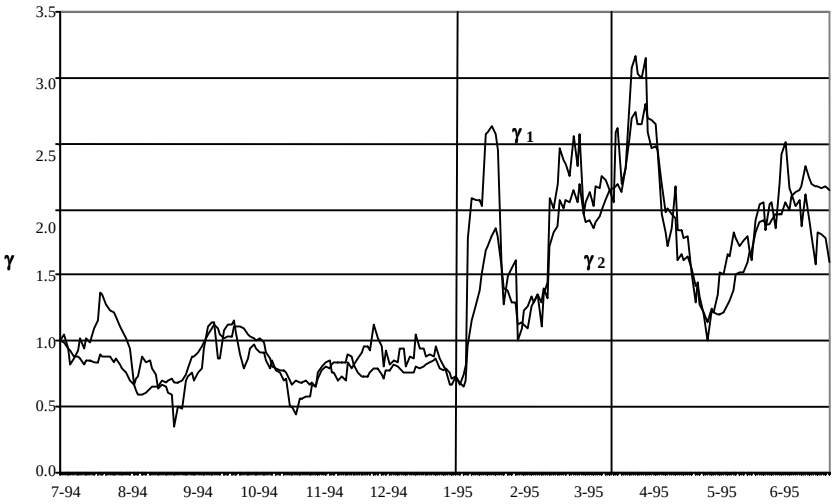


Figure 4: Relative volatility OSE vs. SIMEX

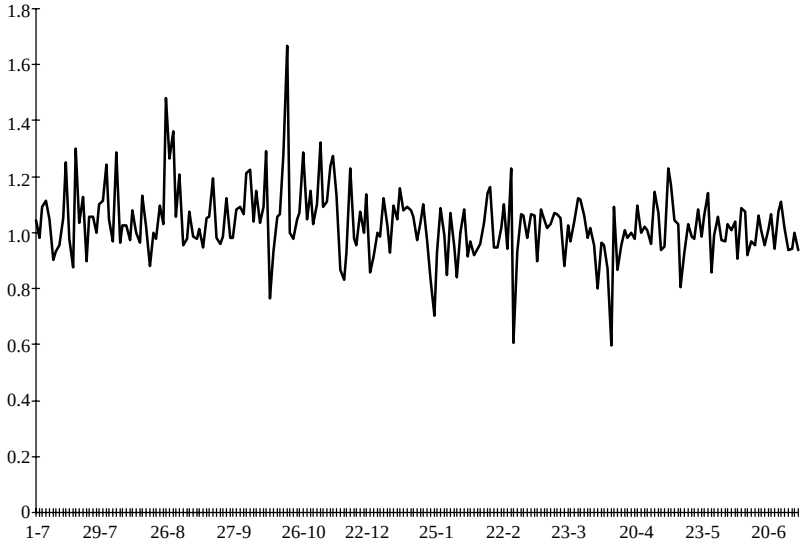


Table 3 shows that OSE prices are significantly more volatile before the earthquake, while the difference disappears after January 17th. This may indicate that SIMEX' margin hikes were successful in dampening volatility.

Table 3: Relative volatility OSE vs. SIMEX

RELVOL				**T-test**	
	Mean	Std Dev	Cases	t-value	p-value
TOTAL	1.0137	0.117	229	1.78	0.076
period 1	1.0405	0.097	114	4.45	0.000
period 2	0.9872	0.128	115	-1.07	0.286

Liquidity

Figure 5 presents trading activity for Nikkei futures on SIMEX. Daily trading activity clearly increases after the Kobe earthquake and remains at a higher level through the rest of the sample period. Figure 6 shows the relative importance of SIMEX during the first three months of 1995 proxied by the number of transactions. It appears that the OSE became relatively more important after the earthquake hit Kobe, which may at least partly be a consequence of the increased transaction costs on SIMEX due to the margin hikes.

Figure 5: Trading activity in SIMEX Nikkei futures

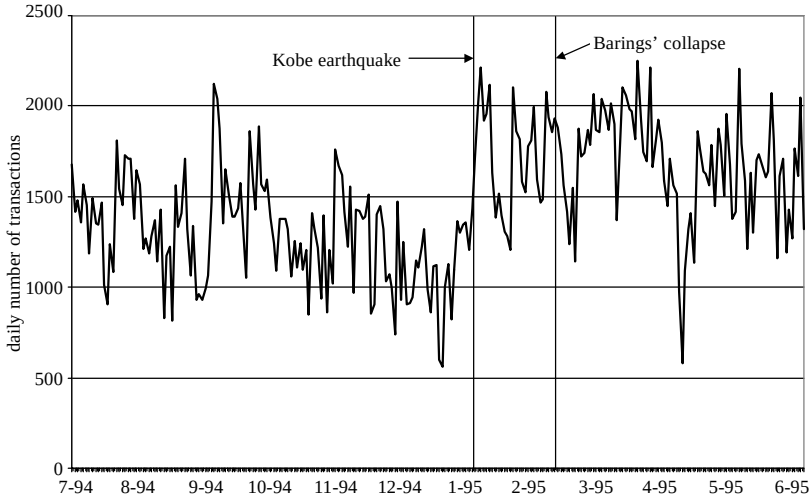
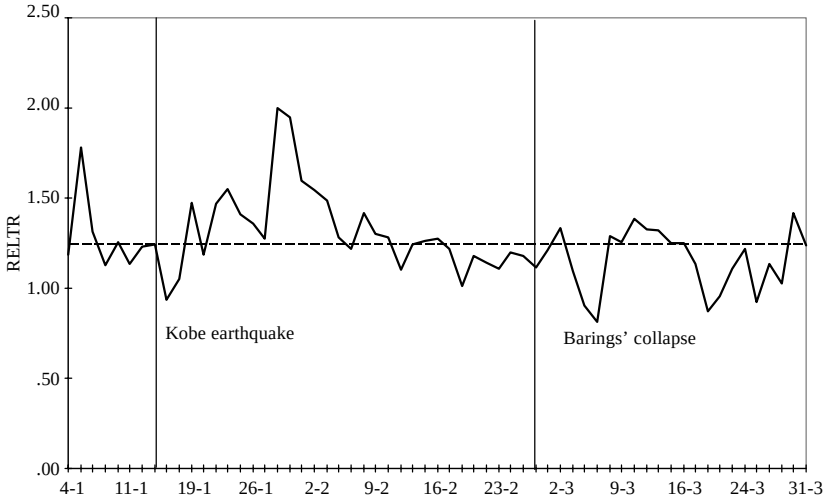


Figure 6: Relative trading activity OSE vs. SIMEX (Jan.-March '95)



Depth

While the OSE is clearly the most important market as far as open interest positions is concerned, the relative importance of SIMEX increased after the Kobe earthquake in times of higher volatility (see Figure 7). This may partly be due to the preference for open-outcry markets (see Section 2.3), but the increased trading activity of Leeson may also have played a role. Barings' position amounted to 60% of the total open interest position in SIMEX March contracts on February 23rd.

Transaction costs: the daily average quoted bid-ask spread

Figure 8 presents the daily average quoted bid-ask spread on SIMEX. It is clear that the spread didn't rise substantially after the earthquake. This was probably due to the increased liquidity which kept spreads down. After Leeson had fled from his office on February 23rd, the quoted spread started to rise and it remained much higher throughout the rest of the sample period. After February 27th traders took advantage of the forced sale by SIMEX of Leeson's positions by widening the bid-ask spread. It may also reflect the higher costs traders incurred because of the raised margin requirements, for which they wanted to be compensated.

Figure 7: Relative open interest OSE vs. SIMEX

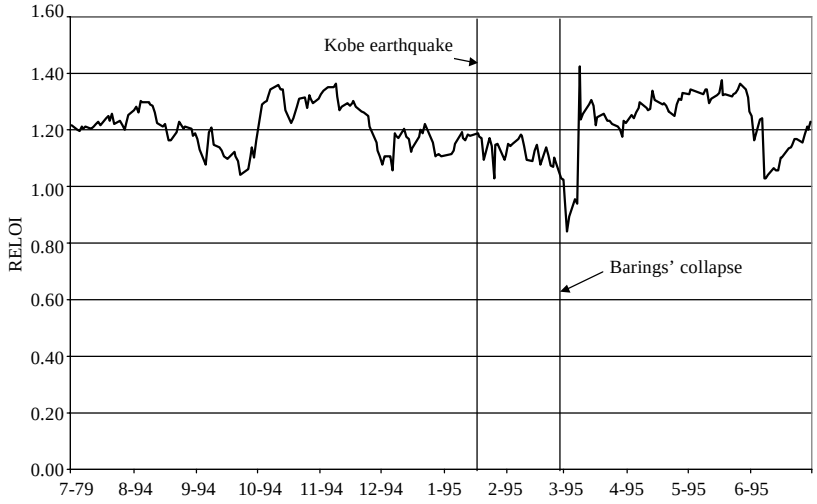
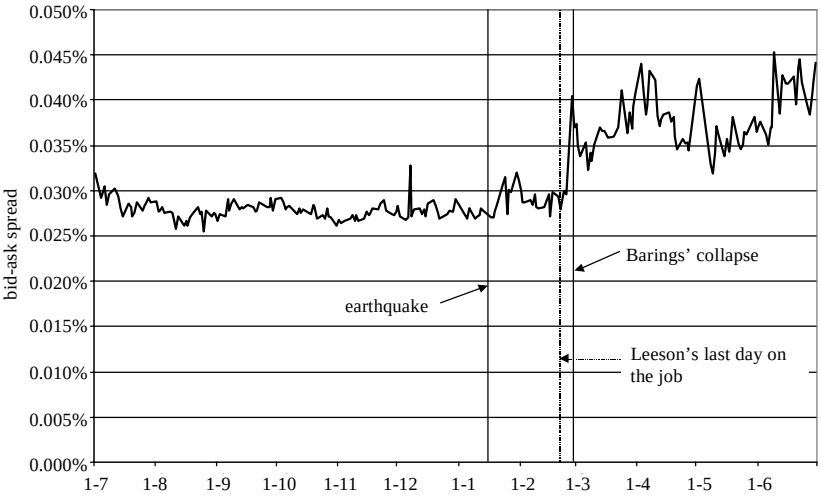


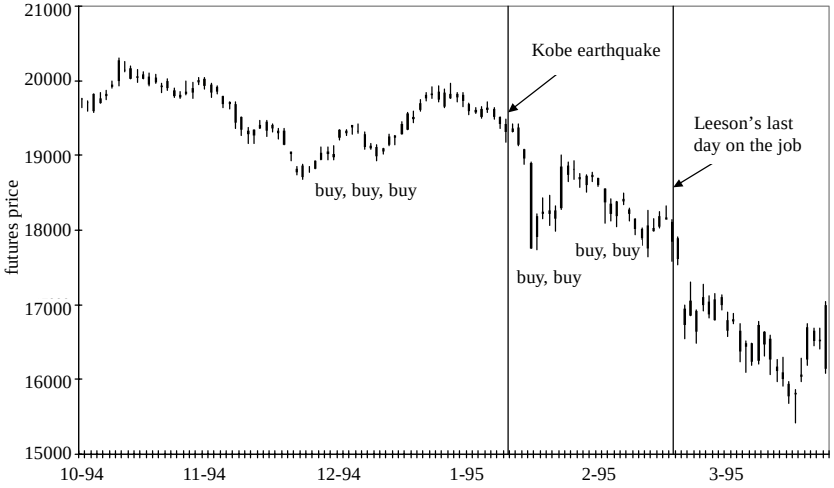
Figure 8: The daily average quoted bid-ask spread on SIMEX



Price effects

From the literature it appears that Leeson was an active trader in Nikkei futures on SIMEX. Leeson (1996) shows that during specific periods, he actively tried to support the market, pushing prices on SIMEX up (see Figure 9). His desperate attempts to 'double' himself out of trouble increased in the final months of 1994 and, in particular the first two months of 1995.

Figure 9: Leeson and SIMEX Nikkei futures



Source: SIMEX tick database and Leeson (1996)

Table 4 presents the results of the T-test. The price difference is calculated as the price on the OSE minus the price on SIMEX.

Over the whole sample, the SIMEX contract appears to be slightly but significantly more expensive than the OSE contract. As expected, price differences during period 1 are insignificant. During period 2 price differences increase and become significant. After the earthquake, the price difference increases even more. After Leeson's departure, price differences decline, but prices in Singapore remain higher than in Osaka. Traders apparently didn't demand a discount to hold SIMEX futures during this period of confusion. Finally, the price difference increases slightly in period 5 and remains significant.

Table 4: Price difference between OSE and SIMEX

DIFF				**T-test**	
	Mean	Std Dev	Cases	t-value	p-value
TOTAL	-0.3383	6.654	56258	-12.06	0.000
period 1	-0.0071	6.061	20438	-0.17	0.876
period 2	-0.5391	5.325	6567	-8.20	0.000
period 3	-0.7086	6.666	6781	-8.75	0.000
period 4	-0.4080	8.364	2733	-2.55	0.011
period 5	-0.4775	7.320	19739	-9.16	0.000
LAGDIF				**T-test**	
	Mean	Std Dev	Cases	t-value	p-value
TOTAL	-0.3427	26.0421	55020	-3.09	0.002
period 1	-0.0853	9.028	19868	-1.33	0.183
period 2	-0.6778	14.599	6300	-3.68	0.000
period 3	-0.7581	10.767	6694	-5.76	0.000
period 4	-0.6605	12.380	2710	-2.78	0.006
period 5	-0.3098	41.291	19448	-1.05	0.295

Doubling

Table 5 presents our results regarding the doubling activities of Nick Leeson. During period 1, the relationship between price movements and trading volume was weakly significant when prices declined, while they were completely insignificant when prices were rising. During period 2, the relationship becomes significant in both cases, but much more strongly so when prices were moving down. After Leeson left the market, the relationship remained. This may have been the result of a reversal in the causal relationship: Leeson's positions were unwound in a falling market.

Table 5: Asymmetries in volume-volatility relationships

period	prices	variable	B	SE B	beta	t-value	p-value	R^2	adj.R^2
1	up	return	695.2	1045.3	0.11	0.67	0.510	0.01	-0.01
		C	15968.8	4637.3		3.44	0.001		
	down	return	2482.0	1357.8	0.29	1.83	0.076	0.08	0.06
		C	9677.7	6122.1		1.58	0.122		
2	up	return	2854.3	1410.3	0.33	2.02	0.051	0.11	0.08
		C	13400.2	6015.5		2.23	0.033		
	down	return	6367.1	1615.4	0.53	3.94	0.000	0.28	0.27
		C	-1600.5	7576.2		-0.21	0.834		
3	up	return	3178.6	956.9	0.47	3.32	0.002	0.22	0.20
		C	10693.5	4557.0		2.35	0.024		
	down	return	4890.6	1214.5	0.53	4.03	0.000	0.28	0.26
		C	1750.7	6343.4		0.28	0.784		

period 1: 1 July – 31 October 1994
period 2: 1 November 1994 – 23 February 1995
period 3: 25 February – 30 June 1995

6 Conclusions

This paper examines price discovery of Nikkei stock-index futures both on the Osaka Securities Exchange (OSE) and the Singapore International Monetary Exchange (SIMEX), around the Kobe earthquake of 17 January 1995, and the collapse of Barings bank on February 27th.

The first aim of this paper was to examine whether a shock to the economy such as an earthquake and the failure of a large market participant cause a dramatic change in the information asymmetries, liquidity, depth and trading costs in the market. We study individual variables and conclude that the above-mentioned events did have a large impact. Volume and volatility rise significantly after both events. Interestingly, the earthquake does not have a large impact on the bid-ask spread on SIMEX, while Barings' collapse does seem to have an effect.

An interesting aspect of this paper is the fact that we investigate a financial product that is traded simultaneously on two markets. Apart from examining the absolute effect on individual variables, we are able to examine the relative effect. Furthermore, we are able to examine the effectiveness of the response by the two exchanges to the events. The changes in margin requirements on SIMEX seem to have been only marginally effective. Prices on SIMEX are slightly higher throughout the sample, indicating an impact of Leeson's massive purchases on SIMEX, as well as a perceived absence of systemic risk in the aftermath of Barings' failure.

The second aim of the paper is to examine the trading strategy of Nick Leeson more closely. We find evidence months *before* the actual collapse, that Leeson

could be described as a 'doubler.' By continuously doubling his position, Leeson tried to trade his way out of the mountain of losses, much like naive players in a casino continuously double their position, because they think it is impossible that the ball for instance falls on black ten times in a row. We claim that, using the proper information, it is possible to recognize a doubler such as Leeson sooner. If you do recognize such a trader, you could take him out of the market sooner, limiting systemic risk.

An important aspect of doublers is that their trading strategy produces normally distributed returns with a high mean for an extended period of time, followed by a very bad event. Among other things, this has important consequences for the effectiveness of Value-at-Risk controls.

References

Andersen, T. G., and T. Bollerslev, 1998, "Deutsche Mark-Dollar Volatility: Intraday Activity Patterns, Macroeconomic Announcements and Longer Run Dependencies," *Journal of Finance* 53, 219-265.

Berkman, H., and O.W. Steenbeek, 1998, "The Influence of Daily Price Limits on Trading in Nikkei Futures," *The Journal of Futures Markets*, vol. 18, no. 3, 265-280.

Brown, K. C., W. V. Harlow, and S. Tinic, 1988, "Risk Aversion, Uncertain Information, and Market Efficiency," *Journal of Financial Economics* 22, 355-385.

Fremault Vila, A., and G. Sandmann, 1996, "Floor Trading versus Electronic Screen Trading: An Empirical Analysis of Market Liquidity in the Nikkei Stock Index Futures Markets," Working Paper London Business School.

Foster, F. D., and S. Viswanathan, 1993, "The Effect of Public Information and Competition on Trading Volume and Price Volatility," *Review of Financial Studies* 6, 23-56.

Gapper, J., and N. Denton, 1997, *All that glitters; the fall of Barings.* London: Penguin Books.

George, T. J., G. Kaul, and M. Nimalendran, 1991, "Estimation of the Bid-ask Spread and Its Components: A New Approach," *Review of Financial Studies*, vol. 4, no. 4, 623-656.

Glosten, L. R., and P. Milgrom, 1985, "Bid, Ask and Transaction Prices in a Specialist Market with Heterogeneously Informed Traders," *Journal of Financial Economics* 14, 71-100.

Glosten, L. R., 1994, "Is the Electronic Open Limit Order Book Inevitable?," *Journal of Finance* 49, 1127-1161.

Grossman, S. J., and M. H. Miller, 1988, "Liquidity and Market Structure," *Journal of Finance*, vol. 43, no. 3, 617-633.

Hamao, Y., and J. Hasbrouck, 1995, "Securities Trading in the Absence of Dealers: Trades and Quotes on the Tokyo Stock Exchange," *Review of Financial Studies*, 849-878.

Ito, T., and W. L. Lin, 1996, "Race to the Center: Competition for the Nikkei 225 Futures Trade," IMF Working Paper WP/96/117, Washington D.C.: IMF.

Jones, C. M., G. Kaul, and M. L. Lipson, 1994, "Transaction, Volume, and Volatility," *Review of Financial Studies*, vol. 7, no. 4, 631-651.

Kim, O., and R. E. Verecchia, 1991, "Trading Volume and Price Reactions to Public Announcements," *Journal of Accounting Research* 29, 302-321.

Leeson, N., 1996, *Rogue Trader.* London: Little, Brown and Co.

Lehmann, B. N., and D. M. Modest, 1994, "Trading and Liquidity on the Tokyo Stock Exchange: A Bird's Eye View," *Journal of Finance*, 951-984.

Madhavan, A., 1992, "Trading Mechanisms in Securities Markets," *Journal of Finance* 47, 607-641.

Martens, M., and O.W. Steenbeek, 1997, "Open Outcry versus Electronic Trading Systems: The Case of the Nikkei Futures Market," Erasmus University Working Paper.

Massimb, M. N., and B. D. Phelps, 1994, "Electronic Trading, Market Structure and Liquidity," *Financial Analysts Journal* 50, 39-50.

Miller, M. H., 1993, "The Economics and Politics of Index Arbitrage in the US and Japan," *Pacific-Basin Finance Journal* 1, 3-11.

OSE, 1998, *Business Regulations*. Osaka: OSE.

Pagano, M., and A. Röell, 1992, "Auction and Dealership Markets. What Is the Difference?," *European Economic Review* 36, 613-623.

SIMEX, 1998, *Trading Rules*. Singapore: SIMEX.

Schwert, W., 1990, "Stock Volatility and the Crash of '87," *Review of Financial Studies* 3, 77-102.

Steenbeek, O. W., 1996, "Implicit Transaction Costs on the Markets for Nikkei Futures," in: *Financial Regulation in Japan, Ph.D. thesis*, Amsterdam: Thesis Publishers.

Stoll, H. R., 1989, "Inferring the Components of the Bid-Ask Spread," *Journal of Finance* 44, 115-134.