An Empirical Examination of the SIMEX Nikkei 225 Futures Contract around the Kobé Earthquake and the Barings Bank Collapse

DAVID M. WALSH*
JINWEI QUEK

This study examines the levels and interrelationships of volatility, volume, open interest and effective bid-ask spread on the Nikkei 225 futures contract on SIMEX. The sample chosen is critical; conclusions regarding the effect of the Kobé earthquake of January 1995 and the resulting collapse of Barings Bank in February 1995 can be uncovered. The analysis uses graphs of the levels of the variables and an assessment of the variables using a vector autoregression and impulse response functions. Volume and open interest temporarily increased, whereas the increase in effective bid-ask spread is more permanent. This seems to be due to the sensitivity that each of the variables develops to volatility as a result of these information shocks.
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*Correspondence author, State Street Global Advisors, Suite 4401, Level 44, Gateway, 1 Maquarie Place, Sydney, Australia.

- *David Walsh is senior Quantitative Manager at State Street Global Advisors, Sydney, Australia.*
- *Jinwei Quek is in the Department of Accounting and Finance at the University of Western Australia.*

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INTRODUCTION

On 17 January 1995, an earthquake shook the city of Kobé in Japan. Approximately 6 weeks later, on 27 February, an aftershock of this earthquake occurred. Massive losses accruing to the Barings Bank subsidiary in Singapore were uncovered, leading to the worldwide failure of Barings Bank itself. The losses in Singapore were the result of the actions of a single trader, Nick Leeson, who took a number of large speculative positions in Nikkei 225 index futures and futures options through the Singapore International Monetary Exchange (SIMEX). The earthquake in Kobé had the effect of reducing the Nikkei Index to such an extent that the losses eventually due to Barings totaled over US$700m.

In this article, the rights and wrongs of the actions of the main players in this drama are not contemplated. Instead, the central study is on the performance of the futures market and its exogenous and endogenous variables. Intuition (and some theoretical research; see, for example, Wall, Tallman, and Abken, 1996) suggests that failure of a large market participant will cause a dramatic change in the information asymmetries, liquidity, depth and trading costs in that market, and in the sensitivity of market variables to each other. It may also increase the probability of a market breakdown.

To examine these issues, the individual market variables that might have been affected by these two events are examined. The variables considered are the index value itself, its volatility, futures trading liquidity (proxied by trading volume as number of trades), transaction costs (effective bid-ask spread) and depth (open interest). This allows assessment of the interaction between market variables before and after both of these events. The framework for this is a vector autoregression (VAR), which is estimated, and the impulse response function that results for each variable examined. It is also possible to assess whether market quality, measured in terms of market variables, was also affected.

This type of study is interesting in a number of ways. It yields conclusions regarding the specific market of interest, allowing us to reflect on whether SIMEX was able to handle both external (Kobé) and internal (Barings) shocks. It will also indicate to us how each variable might react in future to similar shocks in similar markets.[1] Finally, this article shows another use for vector autoregressions (VARs) in finance research—the use of impulse response functions is central to the analysis here.

[1]SIMEX operates as a conventional open outcry futures exchange, making it very similar to many other futures exchanges. Interested readers can reach the SIMEX web site at http://www.simex.com/.

This article contains a brief history of the events surrounding the Barings collapse and provides a critical review of relevant past literature. Also covered are the data utilized in this study and the methodology used.

BACKGROUND

Effects of the Kobé Earthquake

Here the discussion centers on the background to the collapse of Barings bank, and how it was triggered by the Kobé earthquake.[2] In late 1994, Nick Leeson built a position of short straddles,[3] which would have been profitable as long as the Nikkei 225 index remained within a band of 18,500 to 21,000.[4] On January 17 1995, the Kobé earthquake struck, leading to a period of market turbulence.[5] Damage caused by the earthquake was intense, including 5000 deaths. The Nikkei index dropped only slightly during the next three days, with the prevailing sentiment being that the stimulus from reconstruction would probably offset the immediate disruption to production.[6]

Over the weekend, the sentiment changed dramatically, with the Nikkei dropping 1055 points on Monday (23 January, fourth business day). Figure 1 provides a graph of the movement of the Nikkei 225 index over the sample period from 1 September 1994 to 30 June 1995. The fall in the Nikkei 225 index and the resulting rise in volatility increased the risk that the put options sold by Leeson as part of the short straddle would produce serious losses.

Usually, a trader caught with a losing straddle position in a falling market would sell the (underlying) futures contract short, to protect himself against any further downward movement. Leeson did the opposite, increasing his exposure to the further downward movement in the Nikkei 225 index by buying futures contracts. Leeson bought heavily on the Nikkei 225 futures to "shore up the market, and to restore the profitability of his straddles."[7] According to one trader (quoted by Martin, 1995 and by Martin and *Financial Times* writers, 1995), "He was trying to single-handedly hold up the market."

[2]Much of this section draws from Lim and Ng (1995).

[3]A short straddle is a combination of a short call and a short put with the same strike price. Short straddles are used by investors with the belief that the underlying market is to remain stagnant, with low volatility.

[4]See Terazono (1995b).

[5]See Martin (1995).

[6]See Martin et al. (1995).

[7]See Martin et al. (1995).

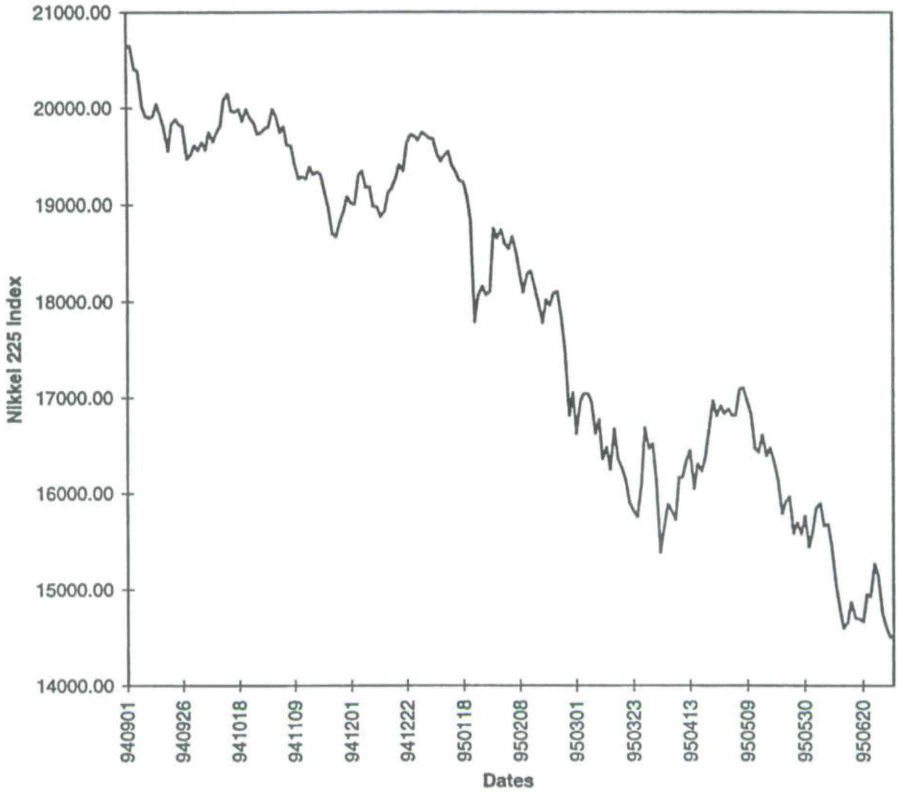

FIGURE 1

The Nikkei 225 index (from 1 September 1994 to 30 June 1995). Plotting the fall of the Nikkei 225 index. The Kobé earthquake date was 17 January 1995 and the announcement of the Barings collapse was 27 February 1995.

The large futures positions Barings built up on both SIMEX and the Osaka Securities Exchange were thought to be offsetting and for arbitrage purposes.[8] This arbitrage strategy involved exploiting price differences between matched positions in the contracts on the two different exchanges. In actual fact, Leeson did not have matched positions on the Nikkei 225 futures, but had gone long on *both* exchanges in the hope of boosting the Nikkei 225 index.

Unfortunately for Leeson, he did not possess the power to move the market, with the index falling to 17,473 on 24 February. Unable to meet its margin requirements, Barings' collapse was announced on Monday 27 February 1995.

[8]See Gapper (1995).

Effects of the Barings Collapse

Financial Times (28 February 1995) reported that Barings' losses represented a potentially damaging blow to SIMEX's reputation and financial strength. "If a broker is unable to meet the costs of its contract, as is apparently in the case with Barings, it is the exchange that must bear the loss, in this case SIMEX . . ."[9] The margin lodged for each futures contract with SIMEX should have been sufficient for "putative losses" in normal circumstances, but Barings' circumstances were not normal.

SIMEX officials assured the market that SIMEX had sufficient funds to meet any liabilities that might arise from the nonperformance or unwinding of Barings' contracts.[10] This assurance was questioned by Baker (1995a), who commented that Barings' losses were potentially larger than the margin figure on both exchanges and that Barings failed to meet the latest margin call on its most recently bought contracts. According to Baker, the summation of these two factors "could leave the authorities facing a deficit on the contracts themselves."

In response to the potential deficit arising from the Barings collapse, SIMEX raised its margins on 27 February (the day of the Barings collapse) from 8% to 15%.[11] Baker (1995a) further commented that the "increased margin is likely to dampen further trading in an already cautious market." Montagnon and Cooke (1995b) said that once SIMEX completed the process of unwinding the Barings position, trading volumes would continue to drop in the future.

Montagnon and Cooke (1995a) similarly reported that SIMEX members were worried that they could face large bills if SIMEX closed the positions at a loss. Under SIMEX's rule 802, members can be collectively liable for any losses up to an estimated US$200m. The rule permits SIMEX to impose levies on members to cover losses once other sources of funds have been used up. The uncertainty of the Nikkei 225 surrounding the Barings collapse meant that SIMEX might accrue losses so great that members would be partially liable.[12]

Baker (1995b) further notes: ". . . the crash that threatened in the early part of the week as the forced selling hit the fan had receded by the weekend as relief spread at the news that all the outstanding futures contracts had been liquidated quickly."[13]

[9]See Baker (1995a).

[10]See Baker (1995a).

[11]SIMEX sets its margin deposits at levels that vary with assessment of the volatility of the underlying market. Up to Friday 24 February, the margin was set at 8%. This was raised to 15% on Monday 27 February.

[12]See Montagnon and Cooke (1995a).

[13]See Baker (1995b).

Another effect arising from the Barings collapse is the damage caused to Japan's financial system. Fifteen Japanese banks had a total of 67.7 billion Yen (US$720m) of nonperforming assets in Baring Securities (Japan), a unit of Barings PLC. Just one week prior to the Barings collapse, several of these banks had loaned funds to Barings to cover the cost of margin payments lodged with the Osaka Securities Exchange. Baker (1995c) comments that these loans are "unlikely to be recovered, given the scale of Barings' losses." With the Japanese financial institutions comprising part of the Nikkei 225 index, and also considering the knock-on effects of a "fragile financial system," it is no wonder that the Nikkei 225 fell and became more volatile during the week of the Barings collapse.

Terazono (1995a) states: "strong futures prices and arbitrageurs' cash market buying had been the main factors holding up share prices . . ." for several weeks before the Barings collapse. The fall in the Nikkei 225 came as a result of these arbitrageurs' liquidating their cash market positions as futures prices plummeted. The index ended 664.24 points down at 16,808.70.

Therefore, for us, the interesting issue is to provide empirical evidence supporting or refuting these reports and to assess whether market quality in SIMEX Nikkei 225 futures changed either as a result of the Barings collapse or due to an exogenous event like the Kobé earthquake.

According to Morse (1995), SIMEX may have suffered negative publicity from the Barings crisis, but its role in making Singapore a primary financial center in Asia has not been diminished. First quarter for 1995 turnover was up 27% to 7.5m contracts, demonstrating that customers have not shied away from the exchange. This may be because it appears that SIMEX eventually did not acquire any losses as a result of the Barings collapse.

Reactions of Market Variables to Shocks

This section briefly reviews the literature on the effects of information shocks on the market variables of interest. As mentioned above, these variables are index volatility, futures contract liquidity (proxied by number of contracts traded), transaction costs (effective bid-ask spread) and depth (open interest). Note that these proxies are at best loose approximations—the concept of liquidity, for example, is "widely used but elusive" (Hasbrouck and Schwartz, 1988), and there are of course other transaction costs besides the bid-ask spread.

The relationship between information events and volatility has been widely documented. However, how this spills over into other market variables is still the subject of considerable interest.

For example, liquidity (or at least, volume) is strongly affected by volatility, probably contemporaneously. If liquidity is the relationship between volume of trading and changes in market price (see, for example, Harris, 1988), then the empirical evidence like that discussed in Karpoff (1987) and demonstrated in articles such as Foster and Viswanathan (1993) would seem support this contemporaneous relationship.

From this, note that transaction costs are strongly linked (through the bid-ask spread) to liquidity and hence volatility shocks. Berstein (1987), Vijh (1990), Petersen and Fialkowski (1993) and more particularly Grossman and Miller (1988) discuss this issue, the last two authors in terms of the supply and demand 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. (However, as Grossman and Miller (1988) point out, the static spread does not reflect this risk transference, but an effective spread will. This is discussed further elsewhere in this article. Hence, the greater the risk, the greater the (effective or quoted) spread. This idea also appears in Glosten and Harris (1988) and Ferguson, Mann, and Schneck (1995).

This has been empirically shown in numerous studies, from Demsetz (1968) through articles like Tinic (1972), Stoll (1978), Ho and Stoll (1980), Hasbrouck and Schwartz (1988), Thompson and Waller (1987, 1988), Followill and Rodriguez (1991) up to Frino and McCorry (1996). Indeed many studies consider the bid-ask spread (usually measured statically) as the primary measure of liquidity (for example, Neal, 1992, and Laux, 1992). In possibly the closest predecessor to the current article, at least methodologically, George and Longstaff (1993) examine many market variables (including level of trading activity) and their impact on (quoted) bid-ask spread. Trading activity (in their study, the time between trades) is a measure of liquidity and was found to be most important determinant of the spread.

Depth is also affected by volatility. Kyle (1985) shows that this comes directly from a model including the presence of an informed trader, and shows that volume will also be affected. Lee, Mucklow, and Ready (1993) state that liquidity is strongly linked with both the bid-ask spread and with the depth of the market, since a specialist can alter either in response to perceived information asymmetries. In other empirical studies, Handa (1992) uses the bid-ask spread as a proxy for depth, and Bessembinder and Seguin (1993) use market depth in futures markets (proxied by open interest) as one of three interrelated market variables in their study. The other two variables were volatility and volume. Evidence from Bessembinder and Seguin suggests that open interest is significantly negatively related to volatility, implying that futures markets thin out as volatility increases in a reaction by traders to the increased risk.

In summary, an information shock would be expected to induce an increase in volatility, at least temporarily. This would in turn have the effect of widening the bid-ask spread, decreasing depth and increasing trading volume. This study seeks to confirm these results, and to answer two further questions:

(i) Did an exogenous information event have a greater or lesser impact than an endogenous event?

(ii) Did the links between these variables change as a result of either of these events?

It is interesting to note that it is only recently that theoretical advances have been made to address the impact of failure of a market participant on market variables and the probability of market breakdown. Hentschel and Smith (1994) and Wall, Tallman, and Abken (1996) are among the first to address this rigorously.

One final point: It may also be possible to address the issue of market quality using these variables. If market quality is defined in terms of sensitivity of the variables to each other, an event may be said to increase or decrease quality of the market. For example, if transaction costs are more sensitive following an event than they were before it, this may imply a decrease in market quality. Note that this is a relative rather than absolute measure of quality.

Next, the discussion proceeds to the data set used and the approach taken to examining the market variables of interest.

DATA AND METHODOLOGY

Data

The data set employed is relatively unusual in academic research.[14] It contains all trades and quotes on all futures contracts traded on the Nikkei 225 index on SIMEX from 1 September 1994 (four months before the Kobé earthquake) to 30 June 1995 (four months after the Leeson event). The total period of the data is just over nine months, 204 trading

[14]Our thanks to SIMEX for kindly providing the data for this study.

days. This leaves plenty of time for the impact of the events of interest to die down, but hopefully minimizes the confounding effect of other events.

SIMEX operates as a open outcry market, like most futures markets. Quotes are submitted via open outcry from traders in the trading pit and are recorded by an exchange official. The trades that result from these quotes are also recorded by an official of the exchange. Hence, in the data set, for each quote, the time of submission can be uniquely identified to within one second, whether it is a bid or an ask, and its quoted price. For each trade, the price and trading time are known, again to within one second. To provide a useable data series, trades are matched to quotes nearest to but preceding the trade.

The other data base utilized in this study contains the daily opening and closing prices for the Nikkei 225 index, the daily open interest and the daily number of contracts traded for each maturing Nikkei futures.

We use trading volume measured as the daily number of contracts traded, and we use daily open interest from the close of the day. Volatility is calculated using the closing Nikkei 225 index values over the sample period. Also, the daily effective bid-ask spread is estimated using the approach suggested by George, Kaul and Nimalendran (1991) (see section below).

Methodology

The methodology for this research is in two steps. First the underlying market variables themselves are examined, using simple techniques, to assess if these variables changed as a result of either event. Then a more detailed analysis of the joint relationship of the variables is conducted, in a VAR setting, before and after each event and over the whole sample. Using impulse response functions, conclusions can be drawn regarding the sensitivities of each variable to shocks in volatility and how this might have changed.

The first results are a graphical examination of open interest, volume and volatility. Volatility ratios like those in Schwert (1990) are calculated and plotted. Volatility ratios provide a simple means of gauging the changes in volatility over the entire sample period.

First, close-to-close returns are calculated and regressed on day of the week dummies for the first 59 days of the sample. (Recall that 29 days is the time between the Kobé earthquake and the Barings collapse.) Then the squared residuals are regressed on two dummy variables—each dummy representing the first and the second 29-day period. That is, the following equations are estimated by OLS:

$$R_t = \alpha_0 + \sum_{i=1}^{4} \alpha_i D_{it} + \varepsilon_t \qquad (1)$$

$$\varepsilon_t^2 = \beta D_t^{P_1} + \gamma D_t^{P_2} + v_t \qquad (2)$$

where

D_i = dummy for day of the week (Monday to Thursday), i = 1 to 4,
D^{P1} = dummy for period 1 (days 1 to 29),
D^{P2} = dummy for period 2 (days 31 to 59, 32 to 60, 33 to 61, . . .),
γ and β = coefficient estimates in the variance equation (2).

The ratio γ divided by β is then calculated and recorded. The process is then repeated by moving period 2 through the data set by one day, estimating the γ from days 32 to 60, 33 to 61, and so on until days 204 to 232 (i.e., extending past the end of the data set just for this calculation). This gives 174 volatility ratios. Note that period P1 is held constant, being the first 29 days (from 940801 to 940907) in the sample. This enables the future volatility periods to be compared relative to a point in time.

This ensures that (i) there are equal numbers of days in each period when the volatility ratios are calculated (which reduces the bias problem suggested by Jones, Kaul and Lipson, 1994); and (ii) the 29 days between the Kobé earthquake and the Barings collapse can be compared with all of the other periods. That is, the 29 days after the Kobé earthquake but before the Barings collapse will supposedly contain the volatility impact resultant from the Kobé earthquake, and will not be "contaminated" by the Barings collapse. The inclusion of the Barings collapse will then inform us whether it had any impact on volatility.

Following this, the effective bid-ask spread is calculated and plotted. Recall that many arguments exist for the use of an effective bid-ask spread, rather than a quoted spread, when measuring transaction costs and to take liquidity into account. The first part of the George, Kaul, and Nimalendran (1991) approach is used to calculate the effective spread. This approach dates from Roll (1984), Glosten (1987) and Glosten and Harris (1988), and uses the serial correlation of the trade stream to estimate the spread. The technique is:

$$S_t = 2\sqrt{-Cov(RD_t, RD_{t-1})} \qquad (3)$$

where

S_t = represents the effective spread.

$RD_t = RT_t - RB_t.$

RT_t = transaction return over period t − 1 to t.

RB_t = bid-to-bid return over period t − 1 to t.

The second step in the methodology is to estimate the joint relationship of the variables. That is, the dynamic structure of the variables before and after the events of interest are to be studied. Vector autoregressions are useful in this regard because they do not impose structural constraints on the parameters. (Kamas and Joyce, 1993). That is, in the absence of any knowledge about "true" relations about how the market variables impact on each other, the application of the VAR technique pioneered by Sims (1982) and popularized by Doan, Littleman, and Sims (1984), enables a model to be formulated. This model allows the capture of empirical regularities in the data.

After exploring the lag space, a consistent number of 3 lags was used, even though this was too long in a number of cases. The model is:

$$BAS_t = \alpha_{0_1} + \sum_{i=1}^{3} \alpha_{i_1} BAS_{t-i} + \sum_{i=1}^{3} \beta_{i_1} NUM_{t-i} + \sum_{i=1}^{3} \gamma_{i_1} OI_{t-i} + \sum_{i=1}^{3} \theta_{i_1} VOL_{t-i} + \varepsilon_{t_1} \tag{4a}$$

$$NUM_t = \alpha_{0_2} + \sum_{i=1}^{3} \alpha_{i_2} BAS_{t-i} + \sum_{i=1}^{3} \beta_{i_2} NUM_{t-i} + \sum_{i=1}^{3} \gamma_{i_2} OI_{t-i} + \sum_{i=1}^{3} \theta_{i_2} VOL_{t-i} + \varepsilon_{t_2} \tag{4b}$$

$$OI_t = \alpha_{0_3} + \sum_{i=1}^{3} \alpha_{i_3} BAS_{t-i} + \sum_{i=1}^{3} \beta_{i_3} NUM_{t-i} + \sum_{i=1}^{3} \gamma_{i_3} OI_{t-i} + \sum_{i=1}^{3} \theta_{i_3} VOL_{t-i} + \varepsilon_{t_3} \tag{4c}$$

$$VOL_t = \alpha_{0_4} + \sum_{i=1}^{3} \alpha_{i_4} BAS_{t-i} + \sum_{i=1}^{3} \beta_{i_4} NUM_{t-i} + \sum_{i=1}^{3} \gamma_{i_4} OI_{t-i} + \sum_{i=1}^{3} \theta_{i_4} VOL_{t-i} + \varepsilon_{t_4} \tag{4d}$$

where

BAS = effective bid-ask spread.

NUM = number of contracts traded on SIMEX daily (volume).

OI = open interest (daily, the depth proxy).

VOL = index volatility.

α, β, γ and θ all represent the coefficients of the above lagged variables.

Since this a symmetric VAR, simple ordinary least squares (OLS) estimation is appropriate to estimate the model.[15] The coefficients and their significance will be estimated for eqs. (4a) to (4d) for five subperiods covering pre- and post-Kobé earthquake, and pre- and post-Barings collapse, and over the entire sample. (That is, pre-Kobé earthquake is from 1 September 1994 to 14 January 1995, and post-Kobé earthquake is from 17 January 1995 to 30 June 1995. Pre-Barings collapse is from 1 September 1994 to 24 February 1995, and post-Barings collapse is from 27 February 1995 to 30 June 1995.)

In the VAR model presented above, the current innovations ε_{ti} are unanticipated but become part of the information set in the next period. This implies that the anticipated impact of a variable is captured in the coefficients of lagged polynomials while the residuals capture unforeseen contemporaneous events (Chishti, Hasan, and Mahmud, 1992). According to Sims (1980), the "estimated coefficients on successive lags tend to oscillate, and there are complicated cross-equation feedbacks". The implication of this is that a direct interpretation of the estimated individual coefficients from the VAR system is very difficult.

In order to analyze the impact of unanticipated volatility shocks on the input variables in a more convenient and comprehensive way, Sims (1980) proposed the use of impulse response functions that are obtained from a moving average representation of the VAR model.

The use of impulse response functions allows us to observe the dynamic behavior of each variable due to a one standard deviation random shock to one of the other variables in the system. Impulse response functions measure the effect of shocks on future value of a series relative to some benchmark case. That is, impulse response functions indicate the direction and magnitude of the effect of a shock in one variable on another. Impulse responses are also able to determine the changes in the sensitivity of the variables to a shock in other variables or themselves.

[15]That is, the estimates produced by OLS are similar to the estimates produced by the VAR provided that the lags are correctly specified. The full informational maximum likelihood technique is able to estimate the VAR coefficients similarly to the OLS approach, due to the fact that no contemporaneous variables are modeled, and there are no exogenous variables to the system used. Jeon and von Furstenberg (1990) also utilize the OLS approach to determine the estimates of their VAR.

Innovations due to the impulse will in general be correlated, reflecting common effects due to the shock. It should be noted that before computing the impulse response functions, one should first orthogonalize the innovations. The Cholesky decomposition method as suggested by Doan (1989) orthogonalizes the variance-covariance matrix of the innovations, and so it is this approach that is used.

Littleman (1984) suggests that the impulse response function should be graphically depicted as it provides a complete description of the dynamic structure of the model which is more comprehensible than the usual representation given in terms of the coefficients of the model's equations. He describes the responses as representing how the system would respond if at rest (that is, if the current and past values of all system variables were zero) and then were subjected to a one-time shock to stock prices. These results are presented in graphical form.

Further, Runkle (1987) and McMillin and Parket (1991) have emphasized that the impulse response functions without confidence intervals to test its significance is like reporting regression coefficients without t-statistics. In Doan (1989), a Monte Carlo simulation of a 1000 draws is used to simulate the confidence intervals, and a two standard deviation band is constructed around the point estimates. If the band includes zero, the effect might be considered insignificant. This confidence interval construction procedure is repeated here.

An added purpose of impulse response functions is that they are able to investigate the persistence of a shock in one of the variables to the system. (Koop, 1996). An impulse response function can be used to assess how long the market takes to respond to a shock to one of the variables, or how long it takes for the shock to "die away." Or, by *cumulating* the responses, the total effect of a shock on a variable can be observed. This is known as the cumulative impulse response function.

The last analysis on the VAR model is the use of a Chow test. This tests for structural changes in the system, and is conducted on each of the OLS equations above (4a to 4d). The Chow test is an adaptation of the F-test for regression coefficients and works by directly testing the explained portion of the regression equation (Maddala, 1989).

The Chow (F) test is

$$F = \frac{RSSp - (RSS1 + RSS2)}{RSS1 + RSS2} \Big/ \frac{(N1 + N2 - 2K)}{K} \tag{5}$$

where

RSSp = Pooled residual sum of squares from regression on the entire sample.

RSS1 = Residual sum of squares for the first period.

RSS2 = Residual sum of squares from regression for the second period.

N1 = Number of days in the first period.

N2 = Number of days in the second period.

K = Number of parameters being estimated (in this case, 12 excluding the constant).

The null hypothesis is that the variables making up each of the two sub periods are identical. Under this hypothesis, the separate equations for periods 1 and 2 can explain no better than the pooled regression, and the F value is at or near zero. The alternative hypothesis is that the separate regressions have better explanatory power than the pooled regression for the whole sample. In this case, the sum of the RSS values for the separate regressions will be significantly less than that for the pooled regression, and the F will be significant. This test is conducted for each variable for both events.

It is important to note that a large variation in the variable of interest does not mean that the Chow test will reject the null hypothesis. The Chow test examines whether the structure of the equation has changed, not the value of the dependent variable.

RESULTS

Individual Variable Analyses

Graphs for the individual variables appear below. The plots list the days from 0 to 204, the total number of days in the sample. The Kobé earthquake is at day 90, and the Barings collapse is at day 119.

In Figure 2, the effective bid-ask spread is plotted over the entire sample. It demonstrates quite clearly that the bid-ask spread has risen sharply after the Barings collapse but is unperturbed by the Kobé earthquake. Hence it suggests that transaction costs did indeed rise as a result of the Barings crash. The spread had an approximate average value of 0.03% before the Barings collapse (up to day 119). Excluding the values that occur from day 120 to day 150, which included a number of outliers, the average spread value from day 151 onward is approximately 0.05%. This represents a 60% increase in the bid-ask spread of the Nikkei 225 futures traded on SIMEX.

Figure 3 shows that volatility has dramatically increased following the Kobé earthquake. This jump happens only four trading days later

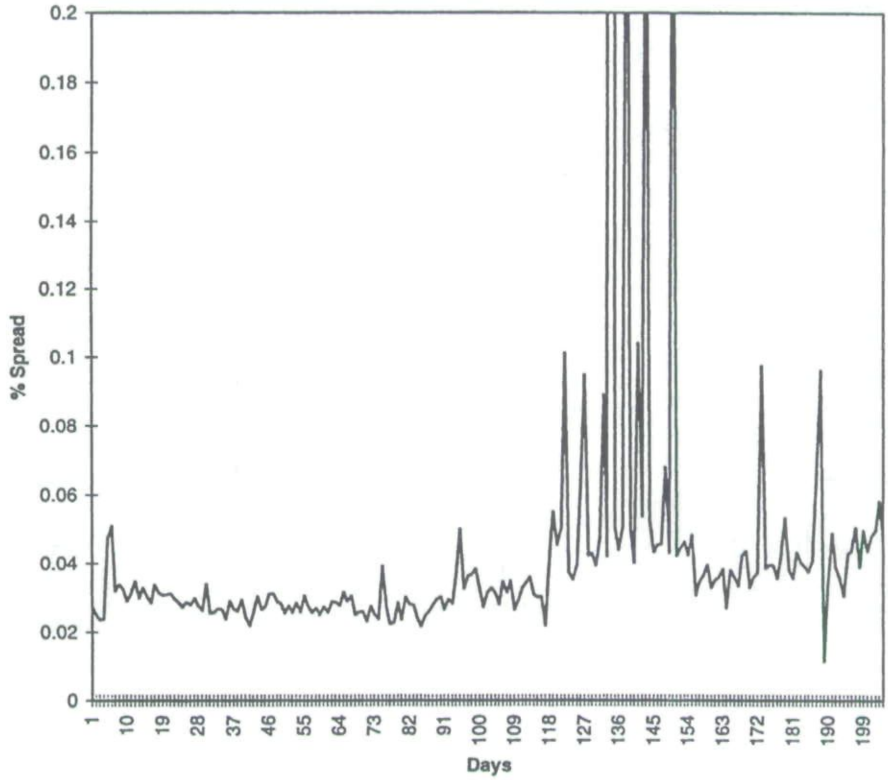

FIGURE 2

Effective bid-ask spread of the Nikkei 225 futures traded on SIMEX (from 1 September 1994 to 30 June 1995). Daily effective bid-ask spread for the Nikkei 225 index futures calculated using the George, Kaul and Nimalendran (1991) approach. Day 90 is the Kobé earthquake, and day 119 is the Barings collapse.

because it took the market that amount of time to assess the impact of the earthquake. In Figure 4, which is the plot of the volatility ratios, there is an increase in volatility from period 58 onwards. Period 58 is from 6 December 1994 to 20 January 1995. This 29 day period had a volatility 3 times greater than the first period in August 1994. This increases shortly to 4 times, and stays high.

The Barings collapse is not expected to have any impact on the Nikkei 225 index as it is highly unlikely for one trader to move the prices of 225 stocks. However, the results show that volatility did increase significantly on day 119 (in Figure 3), the day of the Barings collapse. As expected, the increase in volatility due to the Barings collapse is not as large as the increases caused by the Kobé earthquake. Why then did volatility

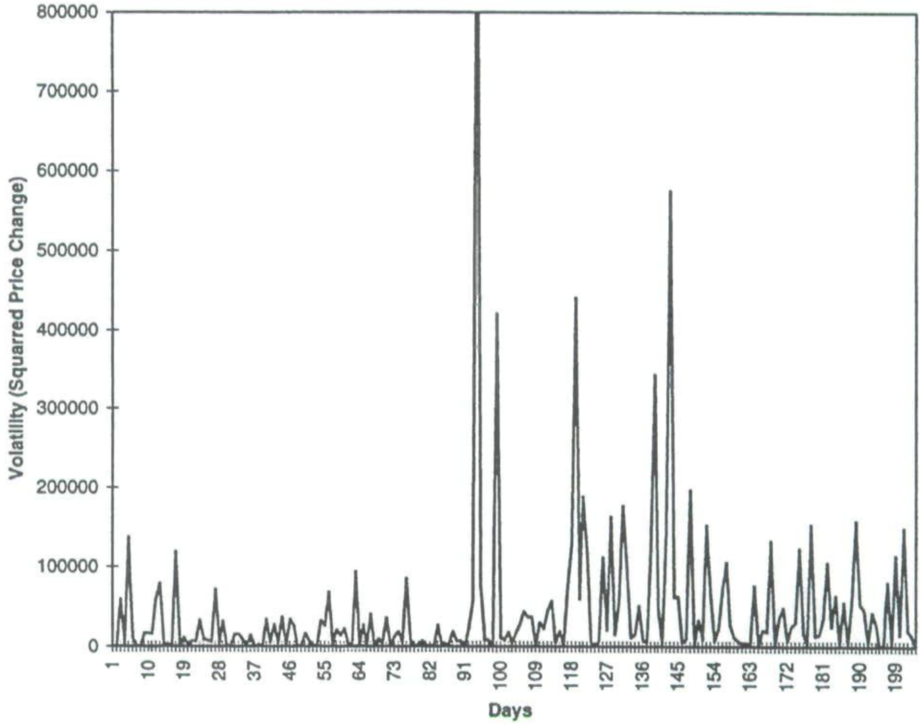

FIGURE 3

Volatility of the Nikkei 225 index (from 1 September 1994 to 30 June 1995). Volatility (calculated as squared price changes) for the Nikkei 225 index. Day 90 is the Kobé earthquake, and day 119 is the Barings collapse.

increase when theoretically, the derivative of a 225 stocks index is not able to influence the movements of the 225 stocks themselves?

One possible reason for the volatility increase lies in the fact that, as mentioned above, 15 Japanese banks had a total of 67.7 billion yen of non-performing assets in Barings Securities (Japan), a unit of the failed Barings PLC.[16] The fear of a financial disaster in Japan due to its "fragile financial system" may have led to the short spike in volatility. This spike, however, is temporary. Looking at Figure 4, period 85 to period 87 (the Barings collapse is in this period) had a short spike, and returns back to roughly 4 times the volatility of the first period.

Figure 5 is a plot of the volume of Nikkei 225 futures contracts (nearest dated maturity) traded daily on SIMEX. The interesting point to note is that at both events, volume increases, with volume increasing more for the Kobé earthquake than for the Barings collapse. Although not easily discernible from the graph, overall volume appears to still be

[16]See Baker (1995c).

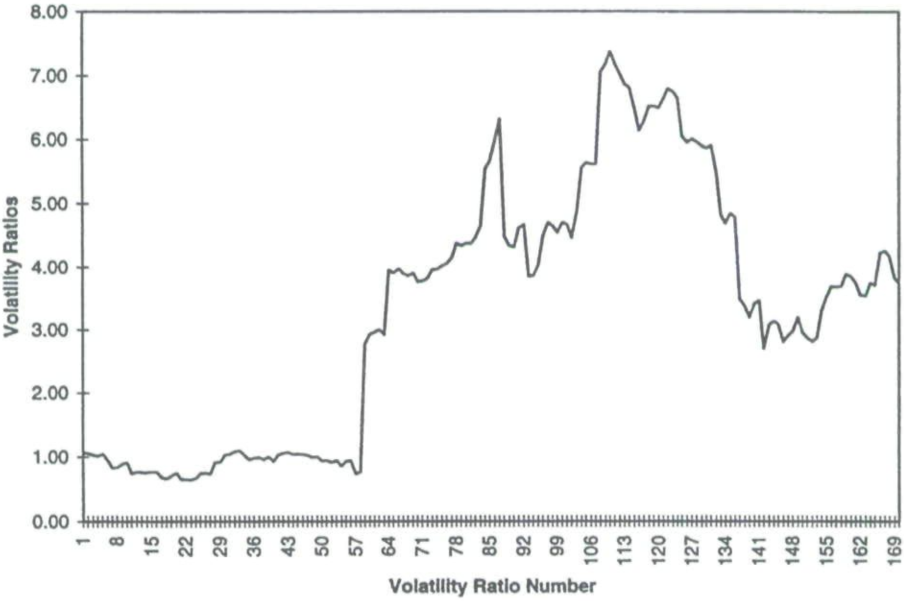

FIGURE 4

Volatility ratios of the Nikkei 225 index (from 1 September 1994 to 30 June 1995). Volatility ratios for the Nikkei 225 index. These are calculated as the ratio of γ to β in the following data)—ratio 1 is using the first period 2, ratio 2 is using the second period 2, and so on:

$$R_t = \alpha_0 + \sum_{i=1}^{4} \alpha_i D_{it} + \varepsilon_t$$

$$\varepsilon_t^2 = \beta D_t^{P_1} + \gamma D_t^{P_2} + v_t$$

where: D_i = dummy for day of the week (Monday to Thursday), i = 1 to 4, D^{P1} = dummy for period 1 (days 1 to 29), D^{P2} = dummy for period 2 (days 31 to 59, 32 to 60, 33 to 61,...), γ and β = coefficient estimates in the variance equation (2).

on an upward trend after both events, demonstrating that the demise of Barings had no effect on the volume of the Nikkei 225 futures.

Figure 6 plots the proxy for the depth of the market—open interest. Interestingly, the Kobé earthquake (day 90) increased the level of open interest (depth) of the market while the Barings collapse (day 119) decreased it (probably due to the unwinding of Barings contracts). The period between the Kobé earthquake and the Barings collapse has an increased open interest compared to other periods. This is because (as mentioned above) Leeson started buying Nikkei 225 futures in the hope of pushing up the futures price such that his options on the Nikkei 225 futures would remain in the money. The result was that when Barings left the market, the open interest resumed its levels as if Barings had never entered the market.

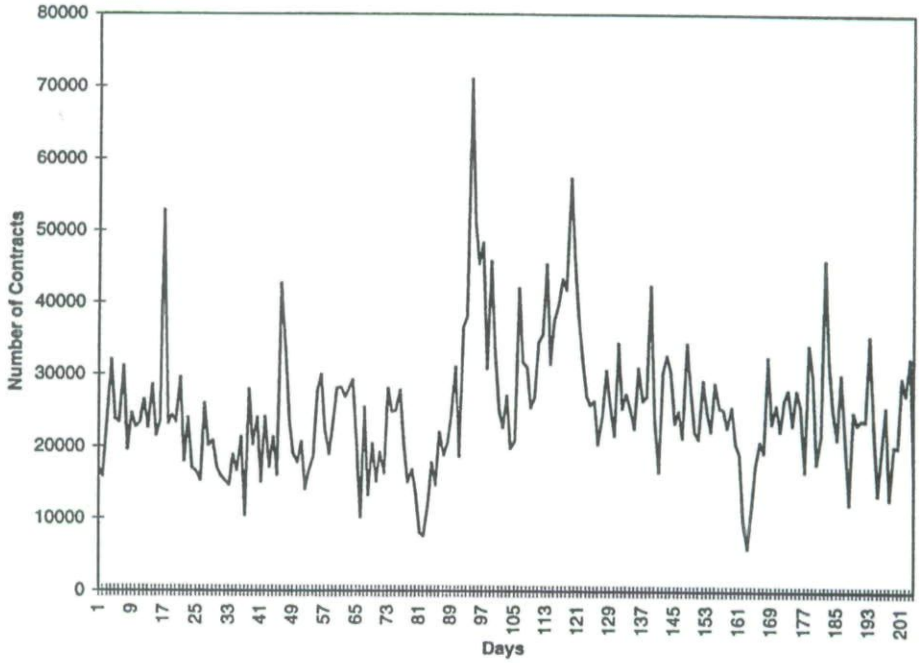

FIGURE 5
Volume of Nikkei 225 futures contracts traded on SIMEX (from 1 September 1994 to 30 June 1995). Volume of trading (number of trades) for the Nikkei 225 index futures contract on SIMEX. Day 90 is the Kobé earthquake, and day 119 is the Barings collapse.

Dynamic Analysis (VARs)

The results for the OLS estimation on each of the four equations in the VAR appear in Tables I and II. The results of the Chow test appear here. (Note that a Chow test for volatility was not conducted, as it is the exogenous variable. It seems impossible that the endogenous market variables are capable of explaining the index volatility.)

The effective bid-ask spread did not fail the Chow test, suggesting that although the value of the spread increased substantially, the driving forces behind it (and hence the structure of the equation) did not.

Overall liquidity as measured by volume traded is thus considered structurally unchanged by either event, and in fact still improving. This is confirmed by the Chow test results—1.01 for the Kobé earthquake in table I and 0.63 for the Barings collapse in Table II, insignificant at the 5% level.

The Chow test indicates a structural break for open interest for both events (refer to Tables I and II). This means that the open interest (depth) of the market is structurally different before and after the Kobé earth-

FIGURE 6

Open interest of Nikkei 225 futures contracts traded on SIMEX (from 1 September 1994 to 30 June 1995). Open interest for the Nikkei 225 index futures contract on SIMEX. Day 90 is the Kobé earthquake, and day 119 is the Barings collapse.

quake, and also different before and after the Barings collapse. This is expected because both events were so close to each other that discovering that one event had a structural change would inevitably include the effects of the other event. If the period between the Kobé earthquake and the Barings collapse was removed, it seems that there would be no evidence of a structural change, but a Chow test cannot prove this. Overall market depth appears to be fairly constant.

The structure of the open interest equation seems to have changed in that the bid-ask spread which formally was a strong explainer of open interest has lost its effect, and the effect has been taken over by volume, and by lagged open interest itself. This can be explained by noting that the open interest was substantially affected by Leeson attempting to reposition his portfolio to reduce his exposure, rather than responding to the information contained in the spread.

Impulse response functions for the market variables are presented next. Figures 7 to 9 give these graphs for the response of bid-ask spread, volume and open interest to a volatility impulse. In these, a one standard

TABLE I

Dynamic VAR Estimation Results before and after the Kobé Earthquake of January 17, 1995 (Sample Period from 1 September 1994 to 30 June 1995)

Dependent Variables		*0*		*1*	*2*	*3*	*4*	R^2	*D-W*	*Chow Test*
				Explanatory Variables						
BAS		Const.	Lags	BAS	NUM	OI	VOL			
	Before	2.16E-02	1	0.31	7.54E-08	−2.22E-07	1.30E-09			
	Kobé	*(2.96)*		*(2.62)*	(0.95)	(−1.57)	(0.06)			
			2	−0.15	1.43E-07	−3.60E-08	−9.80E-09			
				(−1.16)	(−1.11)	(−0.21)	(−0.44)			
			3	0.25	−9.24E-08	1.69E-07	3.12E-08			
				0.00	(1.40)	(1.40)	(1.40)			
								0.32	2.02	
	After	0.27	1	−4.88E-03	2.43E-06	−2.54E-06	−1.69E-07			
	Kobé	(1.14)		(−0.05)	(0.59)	(−0.44)	(−0.73)			
			2	5.21E-03	−4.37E-06	7.73E-06	1.50E-07			
				(0.05)	(−1.00)	(1.01)	(0.65)			
			3	−2.12E-02	3.49E-06	−7.66E-06	7.05E-08			
				(−0.21)	(0.89)	(−1.34)	(0.31)			
								0.04	1.99	0.34
NUM	Before	Const.	Lags	BAS	NUM	OI	VOL			
	Kobé	869.19	1	161788	0.29	−0.13	−0.03			
		(−0.07)		(0.82)	*(2.19)*	(−0.56)	(−0.90)			
			2	131817	0.15	0.12	−0.01			
				(0.62)	(1.11)	(0.40)	(−0.38)			
			3	53206.74	0.04	0.04	−0.06			
				(0.24)	(0.29)	(0.22)	(1.53)			
								0.42	1.88	
	After	38051	1	−4297	0.23	4.95	−0.03			
	Kobé	(0.29)		(−0.08)	(0.10)	(1.55)	(−0.20)			
			2	−17875	5.62	−7.13	−0.28			
				(−0.32)	*(2.32)*	(−1.67)	*(−2.20)*			
			3	−32635	−1.63	1.64	−0.14			
				(−0.58)	(−0.74)	(0.51)	(−1.09)			
								0.19	2.03	1.01
OI	Before	Const.	Lags	BAS	NUM	OI	VOL			
	Kobé	−610	1	222884	−0.11	1.03	0.00			
		(−0.10)		*(2.18)*	(−1.61)	*(8.38)*	(−0.01)			
			2	359858	−0.18	−0.06	0.07			
				(3.30)	*(−2.53)*	(−0.41)	*(3.35)*			
			3	−125752	0.08	−0.06	−0.02			
				(−1.11)	(1.05)	(−0.58)	(−1.25)			
								0.83	1.89	
	After	6963	1	758.32	−0.04	0.98	0.00			
	Kobé	(1.63)		(0.41)	(−0.50)	*(9.24)*	(0.48)			
			2	996.84	−0.01	−0.11	0.01			
				(0.54)	(−0.13)	(−0.80)	(1.28)			
			3	400.45	0.01	0.07	0.00			
				(0.22)	(0.17)	(0.66)	(−0.96)			
								0.84	1.96	*3.21*

Notes: Numbers in parentheses are *t*-statistics. Figures in *italics* indicate significance at the 5% level.

TABLE II

Dynamic VAR Estimation Results before and after the Barings Collapse of February 27, 1995 (Sample Period from 1 September 1994 to 30 June 1995)

Dependent Variables		*0*		*Explanatory Variables* *1*	*2*	*3*	*4*	R^2	*D-W*	*Chow Test*
BAS		Const.	Lags	BAS	NUM	OI	VOL			
	Before	0.02	1	0.25	7.93E-08	−9.03E-08	1.29E-08			
	Barings	*(3.95)*		*(2.38)*	(1.27)	(−0.87)	(2.92)			
			2	−0.13	2.07E-07	−1.25E-07	−1.24E-08			
				(−1.15)	(3.16)	(−0.91)	(−2.77)			
			3	0.6	−6.23E-08	1.74E-07	5.93E-09			
				(1.50)	(−0.91)	(1.75)	(1.27)			
								0.42	1.94	
	After	0.03	1	0.02	6.84E-06	9.84E-07	−4.77E-07			
	Barings	(0.07)		(−0.13)	(1.13)	(0.11)	(−1.04)			
			2	−2.80E-03	−5.11E-06	8.52E-06	1.45E-07			
				(−0.02)	(−0.81)	(0.72)	(0.31)			
			3	−0.05	5.88E-06	−1.08E-05	2.12E-07			
				(−0.44)	(1.05)	(−1.31)	(0.49)			
								0.07	1.98	1.06
NUM	Before	Const.	Lags	BAS	NUM	OI	VOL			
	Barings	−2969	1	47582	3.30E-01	0.32	2.80E-03			
		(−0.30)		(0.23)	*(2.67)*	(1.56)	(0.33)			
			2	23878	3.60E-01	−0.22	1.10E-02			
				(0.11)	(2.79)	(−0.83)	(−1.19)			
			3	−271945	2.90E-03	0.09	−3.50E-03			
				(−1.26)	(0.02)	(0.46)	(−0.39)			
								0.45	1.98	
	After	14346	1	−133	0.29	−5.42E-03	3.74E-03			
	Barings	(1.47)		(−0.04)	*(2.08)*	(−0.02)	(0.36)			
			2	2543	−0.12	2.63E-01	−8.34E-03			
				(0.95)	(−0.84)	(0.98)	(−0.78)			
			3	−484	0.25	−2.53E-01	−5.40E-04			
				(−0.17)	(1.91)	(−1.33)	(−0.05)			
								0.18	2.03	0.63
OI	Before	Const.	Lags	BAS	NUM	OI	VOL			
	Barings	−6306	1	256153	−0.07	0.96	1.00E-03			
		(−1.33)		*(2.59)*	(−1.160)	(9.60)	(0.24)			
			2	319993	−0.10	−0.08	1.11E-02			
				(2.97)	*(−1.54)*	(−0.63)	*(2.57)*			
			3	−30691	0.05	0.06	−9.50E-03			
				(−0.29)	−0.7	(0.61)	*(−2.11)*			
								0.90	1.90	
	After	22597	1	991	−1.75E-01	9.18E-01	1.27E-02			
	Barings	*(3.66)*		(0.59)	(−2.01)	(7.35)	(1.94)			
			2	1886	1.13E-03	−8.49E-02	−3.98E-03			
				(1.12)	(0.01)	(−0.50)	(−0.59)			
			3	1613	−6.46E-02	−2.94E-02	5.58E-03			
				(0.94)	(−0.80)	(−0.24)	(0.91)			
								0.75	2.10	*2.78*

Notes: Numbers in parentheses are *t*-statistics. Figures in *italics* indicate significance at the 5% level.

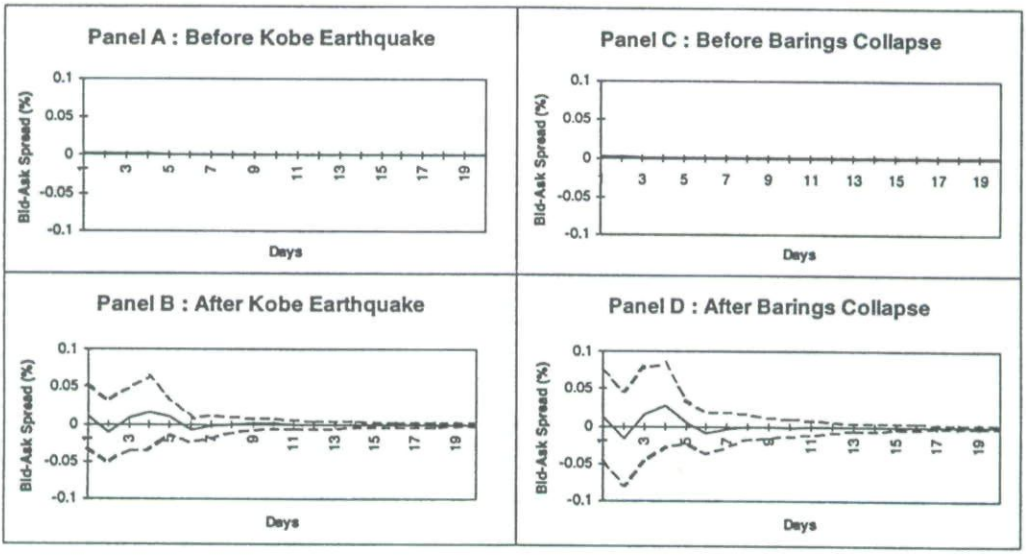

FIGURE 7
Impulse response functions: The reaction of effective bid-ask spread to an impulse in volatility. These graphs show the response of effective bid-ask spread to an impulse in index volatility, before and after the Kobé earthquake and the Barings collapse. Solid lines represent the actual impulse response, broken lines indicate 95% confidence regions about them.

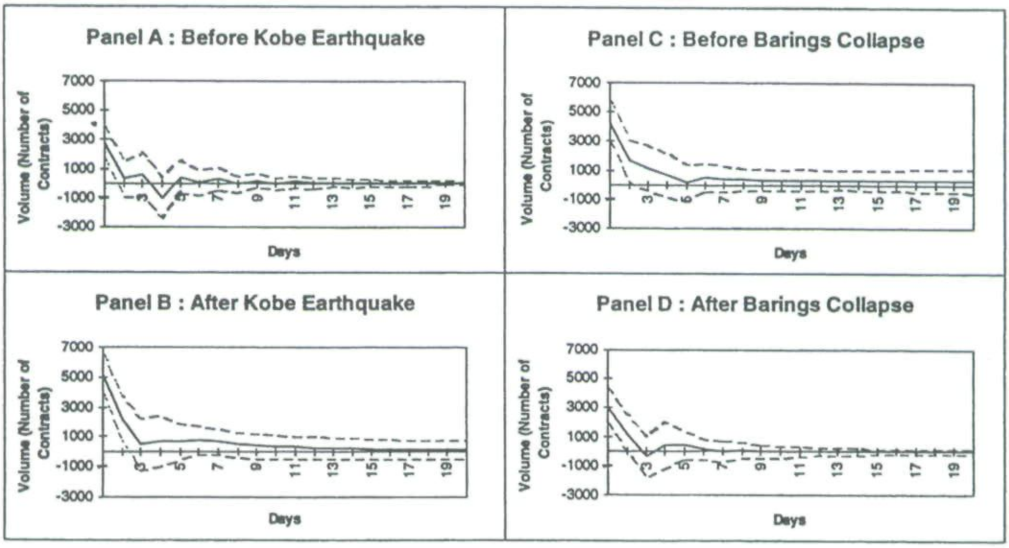

FIGURE 8
Impulse response functions: The reaction of volume to an impulse in volatility. These graphs show the response of volume to an impulse in index volatility, before and after the Kobé earthquake and the Barings collapse. Solid lines represent the actual impulse response, broken lines indicate 95% confidence regions about them.

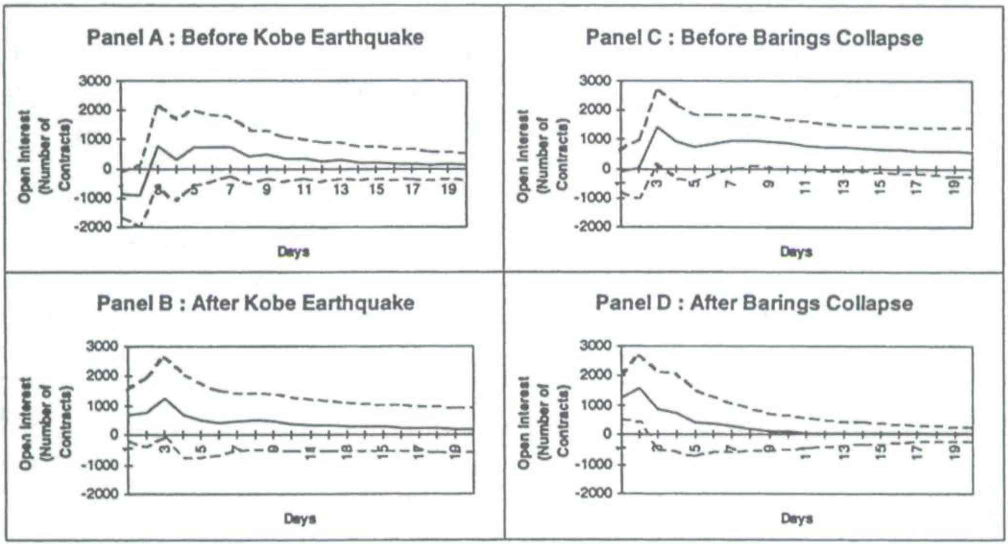

FIGURE 9
Impulse response functions: The response of open interest to an impulse in volatility. • These graphs show the response of open interest to an impulse in index volatility, before and after the Kobé earthquake and the Barings collapse. Solid lines represent the actual impulse response, broken lines indicate 95% confidence regions about them.

deviation shock to volatility is generated, and the response to each variable to these shocks is graphed. Confidence intervals are given.[17]

Figure 7 gives the impulse response functions for open interest, in response to an impulse in volatility.

In Figure 7, these four graphs consider the impact of a one standard error impulse in the index volatility on the effective bid-ask spread. The results are similar for both events, in that before the either event, a shock in volatility produces negligible change to the effective bid-ask spread. After both events, the same shock now has a much bigger impact. Although not shown here, the cumulative effect of a volatility impulse is quite small prior to Kobé, and slightly larger prior to the Barings collapse. After both events, the cumulative effects are much greater, suggesting that the events had a substantial impact on the sensitivity of the spread to volatility. Note that the impact of Barings is greater than that of Kobé, which means that both the Kobé earthquake and the Barings collapse contributed significantly to this increased sensitivity.

[17]Cumulative impulse response functions were also generated, as were impulse response functions for shocks in all of the other variables. These have been deleted for the sake of brevity but are available on request from the authors.

An interesting observation is not only has the sensitivity increased but so has the time taken for the spread to settle down after the impulse. Before Kobé or Barings, although it is a little hard to see, it took the spread approximately 3 days to settle down. Following both events, this has increased to 7 days or more.

Finally, note that the spread responded negatively at first, and then later positively, to the volatility impulse. The initial reaction was a *decrease* in the spread, but the overall (cumulative) impact was positive. This implies that the volatility shock has an overall widening effect on the spread, and hence transaction costs have increased. This positive response agrees with previous studies (for example, Ho and Stoll, 1980), but the initial negative movement is a little puzzling.

Figure 8 gives the responses of volume to the volatility impulse. Note that volume responds positively to the volatility shock. This is as expected (see, for example, Karpoff, 1987).

Figure 8 demonstrates an opposite effect to that of the spread, in terms of the impacts that the events had. Prior to the Kobé earthquake, the response to the impulse was considerably less than after it. However, the reverse is true for the Barings collapse. Also, although again not shown here, the cumulative effect of an impulse after the Barings collapse is only slightly larger than effect prior to the Kobé earthquake, yet the cumulative impact between the events is much larger. Clearly, volume was much more sensitive to volatility as a result of the earthquake.

The most logical conclusion to this is that the Barings collapse reduced the increased volume benefits that arose from the Kobé earthquake. If this increased volume sensitivity is a desirable result, then the Barings collapse had a detrimental effect.

Finally, observe that the time taken for the impulse to become fully incorporated is roughly unchanged as a result of these events, approximately 6 to 8 days. After the Kobé earthquake, the number of days taken increased slightly, but this had reduced again after the Barings collapse.

Figure 9 gives the response of open interest (depth) to an impulse in volatility. Interestingly, like the effective spread, before the Kobé earthquake the initial effect is a decrease in depth, followed by a slow increase leading to a positive impact overall. However, after the earthquake and certainly after the Barings collapse, this effect has disappeared, and the response is always positive. This implies that depth increases as a result of a volatility shock. It seems clear that the Kobé earthquake caused a change in the response of open interest to volatility, and that the Barings collapse did not show much impact at all. (That is, the change took place at the Kobé earthquake, not the Barings collapse.)

The number of lags taken for the effect to settle down is quite long, as many as 20 days prior to the earthquake. However, this had reduced substantially after the Barings collapse, down to approximately 10 days.

SUMMARY AND CONCLUSION

Clearly, the events of January and February 1995 had substantial impact on the volatility of the Nikkei 225 index. Both the Kobé earthquake and the Barings collapse have caused volatility to increase. As a result, or perhaps contemporaneously, Nikkei 225 futures market variables on SIMEX have been greatly affected. Although volatility increased greatly as a result of the earthquake and somewhat less for the Barings collapse, the increase in volume and open interest observed was mainly due to the Barings collapse, and both fell back to roughly the same level some time after the second event. The effective bid-ask spread increased at both events and remained high even four months later. Interestingly, only a structural change in open interest was found through the Chow test, suggesting either that the Chow test has little power or, more likely, that it was the magnitude of the variables that changed, not the structural relationship.

Impulse response functions allowed us to draw some interesting conclusions in the light of these earlier results. The effective bid-ask spread has become much more sensitive to volatility in both the time taken to absorb a volatility shock and in the cumulative extent to which the volatility shock affects the spread. This increased sensitivity to volatility caused the effective spread to increase markedly following the Barings collapse, since this event also induced an increase in index volatility.

However, the volume and open interest remained at approximately the same levels before and after the events. So, while the Kobé earthquake (and, to a lesser extent, the Barings collapse) have caused both variables to have increased sensitivities to volatility, this has not lead to a marked change in either variable. There is no guarantee that it will not, of course.

It seems that transaction costs have increased as a result of these two events, but that liquidity and depth have been largely unchanged. While the Kobé earthquake appears to have caused a short term increase in liquidity and depth, the increase in sensitivity to volatility that it caused has led transaction costs to increase dramatically when the second event occurred. Perhaps such an increase would not have taken place if the first event had not occurred, but this of course is moot point because the second event was caused by the first.

It is also possible to surmise that market quality was affected by these events. The temporary increase in liquidity and depth has been surpassed by a more permanent increase in transaction costs. Transaction costs are also now much more sensitive to volatility. On the other hand, the increased sensitivity of depth and liquidity to volatility may be perceived to be good, allowing the market to be more responsive, but clearly this was only in the short term. In general, it seems that market quality at first increased, due to the increased liquidity and depth due to the Kobé earthquake. However, it seems that market quality then decreased, as a result of the increase in transaction costs, because there was not a matching increase in depth or liquidity.

In extending this study, a number of potential directions suggest themselves. Clearly, a theoretical (and empirically sensible) measure of market quality is required for a study of the real effects of events such as these. Also, since this study examined information events in a derivatives market, it is important to extend this to equity markets, for example. Further, the nature of the failure of a market participant or dealer is of crucial interest if one seeks to dispel the notion that derivatives markets can induce volatility and market breakdown.

This study has addressed some basic results on the performance of certain market variables in a futures market. However, by choosing to examine this period, interesting conclusions can be drawn regarding the way in which market variables (particularly for derivatives markets) respond to exogenous and endogenous information shocks and the resulting volatility change. Clearly, the issue of market quality has not been addressed in any detailed way, but it is equally clear that this a central issue here.

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