Stock Index Futures Listing and Structural Change in Time-Varying Volatility

Sang Bin Lee
Ki Yool Ohk

INTRODUCTION

Stock return volatility has received much attention over the last few years, especially since the October 19, 1987 stock market crash. The contribution of speculation to volatility in financial markets is a concern of policymakers in the United States and other countries. Many of the proposals put forth by the postcrash studies concern trading in stock index futures which, because of their low transaction costs and low margin requirements, are viewed as facilitating speculative activity. The most widespread argument is that futures markets are inherently more volatile than cash markets, presumably because futures market participants are more highly leveraged and speculatively oriented than cash market investors. Such volatility may then *spill over* from futures markets to cash markets by risk arbitrageurs and portfolio insurers.[1] Also, expiring index futures is blamed for drastic price fluctuations on the New York Stock Exchange.

While logical theoretical arguments both support and refute the proposition that the initiation of stock index futures trading destabilizes prices, the issue is so complex that empirical investigation becomes necessary. Some studies compare cash price volatilities before and after the introduction of derivative trade.[2] Most of the studies construct regression models with *a few* explanatory variables (e.g., change in the inflation rate, the volatility of similar security price) to explain the sources of volatility. Then the variances of the residual (i.e., volatility left unexplained by the models' determinants) are compared for the two periods to see whether they

[1]See Bortz (1984) and Miller (1991) for detailed explanations. Kawaller, Koch, and Koch (1990) find that when using minute-to-minute prices, no robust systematic lag/lead relationship is evidenced between futures and index price volatility in either direction. Herbst, McCormack, and West (1987) argue that index futures prices tend to lead those of their cash indices for the Value Line and S&P 500. They find that the average lead is less than one minute for the indices, but there are indications of significant lags of up to 16 minutes in the Value Line and 8 minutes in the S&P 500. Also, Zeckhauser and Niederhoffer (1983) find indications that futures prices appear to have some ability to anticipate movements in the spot index. However, Edwards (1988a, p. 434) suggests that such causality studies tell nothing about the volatility effects of futures trading.

[2]See Lockwood and Linn (1990) and Edwards (1988a, 1988b) for the stock index futures.

Sang Bin Lee is an Associate Professor of Finance at Korea Advanced Institute of Science and Technology.

Ki Yool Ohk is a Doctoral Candidate at Korea Advanced Institute of Science and Technology.

The Journal of Futures Markets, Vol. 12, No. 5, 493–509 (1992)
 CCC 0270-7314/92/050493-17

differ significantly.[3] The effect of trade in stock index futures on cash price volatility is well described by Edwards (1988a, 1988b), who compares cash price volatility before and after the introduction of stock index futures, and then argues that the long-term volatility of the S&P 500 index was greater before futures trading. He finds that excluding the 1979–1982 monetary regime shift period provides a clearer view of the impact of futures markets. However, to be more reliable, this approach must reasonably account for all other determinants of volatility that could have influenced the results. The studies do not control for time-series changes of the other determinants that affect volatility. *Ceteris paribus*, one could uncover any destabilizing effects of futures trading simply by comparing the cash market volatility before and after the creation of the futures market. The goal should be to isolate the impact of futures trading from the other factors influencing cash market volatility.

This article extends existing research, so far almost exclusively conducted for the United States, to major countries that have introduced stock index futures to their stock markets. The effects of trade in stock index futures on stock return volatility in Australia, Hong Kong, Japan, and the United Kingdom are evaluated. Also, as mentioned above, to control for the other determinants of volatility, such as country-specific financial and economic factors and worldwide factors, and to isolate the impact of futures trading from the other determinants of volatility, this study constructs an international portfolio composed of the representative stock indices' returns in five stock markets.[4] To test whether change in volatility occurs around the time that stock index futures are listed on the stock market index, in both individual stock market returns and the international portfolio returns, the modified Levene test statistic suggested by Brown and Forsythe (1974), that is robust under nonnormality, is used.

Furthermore, this study considers whether a particular event, such as the introduction of stock index futures trading, leads to a change in *market efficiency*. The introduction of stock index futures trading may lead to a change in the speed of information flow to the stock market. To examine the effect of futures trading on market efficiency, this study uses the *switching* GARCH (Generalized Autoregressive Conditional Heteroskedastic) model that captures the structural change of time-varying volatility. The ARCH family of statistical models recognizes the temporal dependence of stock return volatility and exhibits a leptokurtic distribution for the unconditional errors from the stock returns generating process. The ARCH model was introduced by Engle (1982) and generalized by Bollerslev (1986, 1987). Examining the descriptive validity of these models, many researchers [e.g., Bollerslev (1987); French, Schwert, and Stambaugh (1987); Akgiray (1989); Schwert (1990); Lamoureux and Lastrapes (1990); and Baillie and DeGennaro (1990)] have found the GARCH model to be an attractive representation of daily stock return behavior.

THE EFFECT OF FUTURES TRADING ON STOCK RETURN VOLATILITY AND MARKET EFFICIENCY

Change in Stock Volatility

Some authors suggest that stock index futures trading increases speculative activity, which in turn destabilizes cash markets and causes higher volatility. However,

[3]See Simpson and Ireland (1982) for the GNMA market, Simpson and Ireland (1985) and Ely (1988) for the treasury-bill market, and Bortz (1984) for the treasury-bond market.

[4]The basic institutional features of these stock exchanges are described in Cohen et al. (1986, pp. 33–36).

Weller and Yano (1987), using a general equilibrium analysis, show that cash market volatility may decrease when futures are introduced. Theoretical analysis of whether speculative trade destabilizes cash markets leads to conflicting conclusions, depending on what assumptions are made.

One viewpoint suggests that speculative trade in futures markets tends to stabilize the cash market. As suggested by Friedman (1953), profitable speculation stabilizes prices, presumably because well-informed speculators tend to buy when prices are low, which pushes prices up, and sell when prices are high, which makes prices fall. Uninformed speculators, on the other hand, will not be successful and will be eliminated quickly from the market. Hence, the speculation caused by the creation of stock index futures leads to a decrease in stock return volatility.

An opposing view suggests that speculation in futures markets destabilizes the cash market. For example, if trading volumes are diverted from the underlying stocks to index futures, the decreased liquidity in the underlying stocks might increase their price volatility. Also, it is well known that expiring stock index futures apparently leads to serious price fluctuations in the stock market. Stoll and Whaley (1987) have studied the volatility surrounding expiration days which include the triple witching days and find that the S&P 500 index volatility increases on expiration days.

The prevalent view, expressed almost daily in the financial press of the U.S. (and now reinforced by similar impressions in the Japanese press) is that stock market volatility is greater in recent years, and that the introduction of a *low cost* speculative vehicle such as stock index futures and options is largely responsible.

The volatility of stock returns can be divided into components attributable to: (i) the variability of stock returns affected by the variability of macroeconomic and financial factors; and (ii) the variability caused by the trading activity of investors. French and Roll (1986) argue that volatility is closely related to information. Information leads to changes in expectations, which in turn leads to changes in prices. The information that affects stock return volatility comes primarily from financial and economic announcements, such as the announcement of the Consumer Price Index, money supply, corporate earnings, and Gross National Product. Another source of volatility is the trading induced by liquidity and asset allocation needs, market-timing decisions, and activities of institutional investors and individual investors to take arbitrage and hedge positions. This type of information is closely related to the volatility attributable to the trading activity of investors. Hence, if the structural change in volatility occurs after the start of trade in stock index futures, it may be ascribed mainly to changes in the trading activities of institutions and individual investors.

Change in Market Efficiency

As mentioned above, volatility is closely related to information. Information leads to a change in expectations, which in turn leads to a change in prices. If information never comes along to cause a reevaluation of the markets, price would be set according to the present value of expected future value and would grow smoothly. According to Lamoureux and Lastrapes (1990), an appealing explanation for the presence of ARCH is based upon the hypothesis that daily returns are generated by a mixture of distributions, in which the rate of daily information arrival is the stochastic mixing variable. In their study, Lamoureux and Lastrapes find that volatilities of daily returns are heteroskedastic and positively related to the rate of daily information arrival. In fact, one can think of return volatility as nothing more than a manifestation of information in the markets.

As suggested by Miller (1991), the low cost of trading index futures makes the futures market the natural entry port for new information. This extra news causes trading activities of individual and institutional investors to change. These changed trading activities are associated with extra return volatility. Then there may be a noticeable difference in the arrival process of new information in the cash market. This implies that there should be a significant difference in the autocorrelation structure of stock volatility around the time that stock index futures are listed on the stock index. This suggests that the autocorrelation of stock volatility decays more rapidly after than before index futures listing and implies that stock index futures make the stock market more *efficient*. The speed at which information is transferred to the stock market is considered the measure of its market efficiency.

THE DATA

This study uses daily index data over a roughly four-year period, from the 500th business day before the start of trade in stock index futures to the 500th business day after trading in stock index futures was introduced in each of five stock markets—Sydney, Hong Kong, Tokyo, London, and New York. The most comprehensive and diversified stock index is chosen for each country. For the Sydney Stock Exchange, the Tokyo Stock Exchange, and the New York Stock Exchange, value weighted stock indexes are used. The Hang Seng Index which is made up of 33 stocks listed on the Hong Kong Stock Exchange is used because the Exchange has no value weighted index of all shares. For the London stock market, the Financial Times–Stock Exchange 100 Share Index is used, which represents 70% of the equity capitalization of all United Kingdom equities at the end of 1987. This is a value-weighted arithmetic index. The data are from the *Financial Times* and the *Asian Wall Street Journal*. The indices used are as follows:

Australia: Australian Stock Exchange's All Ordinaries Share Index,
Hong Kong: Hang Seng Index,
Japan: Tokyo Stock Exchange Index,
U.K.: Financial Times Ordinary Share Index, and
U.S.: New York Stock Exchange Composite Index.

Return is defined as the natural logarithm of value relatives; $R_t = \ln(P_t/P_{t-1})$, where P_t is the stock index value at time t. For a small time interval, such as in daily data, this definition is similar to the arithmetic rate of return.

METHODOLOGY

Modified Levene Statistic and Bootstrap

The null hypothesis that the volatilities for the two subperiods before and after are equal (homoskedastic) is examined, H_{io}: $\sigma^2_{\text{before},i} = \sigma^2_{\text{after},i}$, where i = Australia, Hong Kong, Japan, the U.K., and the U.S.; volatility σ^2 is defined as the variance of the natural log of the value relatives. The alternate is H_{ia}: $\sigma^2_{\text{before},i} \neq \sigma^2_{\text{after},i}$. Hypothesis H_{io} is examined with the Brown–Forsythe (1974) modified Levene (1960) test statistic. In a simulation experiment, Brown and Forsythe (1974) show that the F-statistic rejects the null hypothesis of equal volatilities too frequently if the data have heavier tails than the normal distribution. It is well known that the distribution of stock return is leptokurtic rather than the normal, but that the modified Levene statistic is not sensitive to departures from normality.[5] The modified Levene statistic is compared with the unmodified Levene's statistic, a jackknife procedure, and chi-square test suggested by Layard (1973) which are all found to be less robust under nonnormality, according to Brown and Forsythe (1974).

The modified Levene statistic is calculated as follows. Suppose there are G groups of data, indexed $i = 1, \ldots, G$. Each group contains n_i observations. Suppose σ_i^2 is the volatility of ith group. The null hypothesis is that $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_G^2$. Let x_{ij} be the jth observation in the ith group. The Levene (1960) statistic is computed as follows:

$$z_{ij} = |x_{ij} - \bar{x}_{i\cdot}| \qquad \text{where } \bar{x}_{i\cdot} = \sum_j x_{ij}/n_i$$

$$W = \left[\sum_i n_i(z_{i\cdot} - z_{\cdot\cdot})^2 \Big/ (G-1)\right] \Big/ \left[\sum_i \sum_j (z_{ij} - z_{i\cdot})^2 \Big/ \sum_i (n_i - 1)\right]$$

$$\text{where } z_{i\cdot} = \sum_j z_{ij} \Big/ n_i \quad \text{and} \quad z_{\cdot\cdot} = \sum_i \sum_j z_{ij} \Big/ \sum_k n_k$$

Under the null hypothesis that x_{ij} is independently and identically distributed, W is asymptotically an $F(G-1, \sum_i (n_i - 1))$ distribution. Brown and Forsythe (1974) suggest the modified Levene statistic by replacing the mean $\bar{x}_{i\cdot}$ with a trimmed mean. This study uses a 10% trimmed mean, which is recommended in Brown and Forsythe (1974).

To assess the distribution of the modified Levene statistic in this application, $2k$ daily data are selected randomly from the samples of $2k$ daily stock returns. The randomly selected stock returns are divided into two groups of k stock returns, and the corresponding modified Levene statistic for the k days before and after ($k = 100, 250, 500$) is calculated. This procedure is repeated 1000 times. This yields a *bootstrap* distribution of the modified Levene statistic.[6]

Switching Generalized Autoregressive Conditional Heteroskedastic Model

Many researchers [e.g., French, Schwert, and Stambaugh (1987); Pindyck (1984); Poterba and Summers (1986); Bollerslev (1987); Baillie and DeGennaro (1990); and Lee and Ohk (1991)] note that the volatility of stock market returns changes over time.[7] To test whether a change in market efficiency occurs with the introduction of futures trading, and to consider the time-varying volatility of stock returns, this study uses the modified GARCH model that captures structural change in the autocorrelation of stock volatility. The modified GARCH imposes an autoregressive structure on conditional variance, allowing volatility shocks to persist over time,

[5]Using the stock market return series of each market, sample mean, variance, skewness, kurtosis, and Bera–Jarque statistics are estimated. The Bera–Jarque test, suggested by Bera and Jarque (1981), is performed for the null hypothesis of the normality of the distribution of stock returns. The Bera–Jarque test is a joint test of whether or not estimates of skewness and kurtosis are significantly different from zero. This study's Bera–Jarque test strongly rejects the null hypothesis of normality in stock market return in each stock market. These results are not shown here. Detailed results are available upon request.

[6]See Efron (1982) for detailed explanations.

[7]Lee and Ohk (1991) examine the time-varying volatilities of stock return series and the relationships between expected stock returns and their predicted volatilities in Western Pacific-Basin countries and the United States.

and captures structural shift in *regime*, i.e., change in the level and slope of time-varying volatility (change in the autoregressive structure on conditional volatility) using dummy variables. This modified model is called the *switching* GARCH model.

The switching GARCH model is designed for situations where the coefficients representing a level and an autoregressive structure on the conditional volatility of a GARCH model are constant for a period of time and then change and remain constant at the new level. The switching GARCH model is derived from two GARCH processes as follows:

$$R_t = \beta_0 + u_t \tag{1}$$

$$u_t = \epsilon_t - \theta\epsilon_{t-1} \tag{2}$$

$$\epsilon_t|\Omega_{t-1} \sim N(0, \sigma_t^2) \tag{3}$$

$$\sigma_t^2 = \gamma_{0b} + \gamma_{1b}\sigma_{t-1}^2 + \alpha_{1b}\epsilon_{t-1}^2 \qquad (t = 1, 2, \ldots, t^* - 1) \tag{4a}$$

$$\sigma_t^2 = \gamma_{0a} + \gamma_{1a}\sigma_{t-1}^2 + \alpha_{1a}\epsilon_{t-1}^2 \qquad (t = t^*, t^* + 1, \ldots, T) \tag{4b}$$

In the above model, the dependent variable, R_t, denotes the rate of return at time t; $R_t = \ln(P_t/P_{t-1})$, where P_t is the stock index value at time t. The conditional volatility σ_t^2 is a function not only of last period's error squared but also of its conditional volatility. Scholes and Williams (1977) and Cohen et al. (1980) examine how nonsynchronous trading in individual stocks, bid–ask spreads, and minimum-size price changes can cause serial correlation in stock index returns. Because the ARCH models assume that the conditional error is serially uncorrelated, it is necessary to extract this serial correlation from the first moments of the stock returns and portfolio returns. As suggested by Scholes and Williams (1977); Bollerslev (1987); French, Schwert, and Stambaugh (1987); and Lee and Ohk (1991), the distortion of parameter estimates caused by the serial correlation can be avoided by including a first-order moving average process (MA(1) process). The innovations, ϵ_t, are assumed to follow a conditional normal distribution. The set of all relevant and available information at time $t - 1$ is denoted by Ω_{t-1}.

Since the switching point, t^* (the listing date of stock index futures), is known, eqs. (4a) and (4b) can be represented by one equation with dummy variables for intercept and slope.

$$\sigma_t^2 = \gamma_{0b} + \gamma_{1b}\sigma_{t-1}^2 + \alpha_{1b}\epsilon_{t-1}^2 + \gamma_{0d}D_t + \gamma_{1d}\sigma_{t-1}^2D_t + \alpha_{1d}\varepsilon_{t-1}^2D_t \tag{5}$$

where

$$D_t = \begin{cases} 0 \text{ if } 1 \le t \le t^* - 1, \\ 1 \text{ if } t^* \le t \le T \end{cases}$$

$$\gamma_{0d} = \gamma_{0a} - \gamma_{0b}, \gamma_{1d} = \gamma_{1a} - \gamma_{1b}, \text{ and } \alpha_{1d} = \alpha_{1a} - \alpha_{1b}$$

If no structural change occurs in the mean level and the autoregressive structure on conditional volatility after the start of trade in stock index futures, the coefficients with dummy variables for intercept and slope would not be significantly different from zero. That is, the null hypothesis is H_o: $\gamma_{0d} = \gamma_{1d} = \alpha_{1d} = 0$. The alternate hypothesis, H_a: H_o is not true.

RESULTS AND INTERPRETATIONS

Volatility Change After Listing

Table I summarizes the underlying indices, their futures listing dates, futures value multipliers, and minimum fluctuations. The Nikkei 225 Stock Index was traded initially on the Singapore International Monetary Exchange.

The modified Levene statistic is used to test whether structural change in volatility occurs around the time that stock index futures began trading at each of the five exchanges. To examine the effect of futures trading on volatility and investigate whether the effect is consistent to the time interval of sample, three sampling intervals are used: 100, 250, and 500 trading days before and after the stock index futures listing. The corresponding bootstrap marginal significance levels for the calculated modified Levene values are given in parentheses in Table II.

Table II presents the standard deviations of stock returns in the two periods before and after the index futures listing on the five exchanges using three sampling intervals: 100, 250, and 500 trading days on either side of the index futures listing date. Also, the modified Levene value for three sampling intervals are calculated to test for the equality in volatility of the two subperiods for the five stock markets. For example, the "−/ + 100" column comprises the standard deviations before and after the listing using 100 daily returns immediately before and after the listing, the estimated modified Levene values, and the corresponding bootstrap marginal significance levels. Except for the cases of Australia and Japan, the results appear to be sensitive to the time interval of the sample. In Australia, no significant difference in the volatility of the two periods is found. Hong Kong shows that stock return volatility declines in the short test interval (100 days). In Japan, stock volatility rises in all three test intervals. The U.K. shows that stock volatility increases in the short test interval and the intermediate one (250 days). In the U.S., the volatility rises only in the intermediate test interval.[8]

The different results about the effect of futures trading on stock volatility might be explained in two ways. Stock volatility may be affected by the variability of macroeconomic factors. If macroeconomic changes occur after the initiation of the index futures trading, they may be the cause of stock volatility. The different results from country to country would be understandable in that case. On the other hand, the structure of the various markets may be a major determinant of the impact of futures trading. Amihud, Mendelson, and Murgia (1990) find that the stock market structure has a substantial effect on return volatility in the Italian stock market. The structure of the market differs from country to country. Each market has different trading mechanisms, settlement days, price stabilization mechanisms, forms of taxation, and regulations imposed by government. Amihud and Mendelson (1987) argue that the trading mechanism has a significant effect on stock behavior. Stock exchanges in Australia and Hong Kong operate as continuous trading markets where orders are

[8]This result conflicts with previous studies by Edwards (1988a, 1988b). Edwards (1988a) finds that the shifts in monetary policy, that occurred in both October 1979 and October 1982, have a significant effect on financial asset volatility. By excluding the 10/1/1979–9/30/1982 period (monetary regime shift period) for the U.S., he finds that cash market volatility diminishes after the introduction of futures trading. Excluding the monetary regime shift period provides a clearer view of the impact of futures trading in the sense that it controls for the monetary regime shift—which affects stock volatility. Results similar to those of Edwards are found by the authors of this study when an expanded sample period is used and the monetary-regime shift period for the U.S. is excluded.

Table I
MAJOR STOCK INDEX FUTURES WORLDWIDE

	Australia	Hong Kong	Japan	U.K.	U.S.
Underlying index	All-ordinaries share index	Hang seng index	Nikkei stock average	FT-SE 100	Value line index
Exchange	SFE	HKFE	SIMEX	LIFFE	KCBT
Listing date	Feb. 16, 1983	May 6, 1986	Sep. 3, 1986	May 3, 1984	Feb. 24, 1982
Contract multiplier	Australian $100 × index	Hong Kong $50 × index	¥1000 × index	£25 × index[a]	$500 × index
Minimum fluctuation	0.1 ($10 Aus.)	1.0 (HK$50)	5.0 (¥5000)	0.05 (£12.5)	0.05 ($25)

[a]The futures price quotation is the index divided by 10.

SFE, Sidney Futures Exchange; HKFE, Hong Kong Futures Exchange; SIMEX, Singapore International Monetary Exchange; LIFFE, London International Financial Futures Exchange; KCBT, Kansas City Board of Trade.

Table II
STOCK RETURN VOLATILITY BEFORE AND AFTER INDEX FUTURES LISTING: INDIVIDUAL COUNTRY'S CASE

	Est. Int.		
Country	**−/+ 100**	**−/+ 250**	**−/+ 500**
Australia	0.0104[a]	0.0096	0.0100
	0.0107[b]	0.0092	0.0093
	0.40[c] (0.549)[d]	1.05 (0.328)	1.33 (0.253)
Hong Kong	0.0111	0.0127	0.0154
	0.0086	0.0121	0.0243
	4.78 (0.035)[f]	0.02 (0.887)	0.47 (0.478)
Japan	0.0084	0.0071	0.0065
	0.0120	0.0119	0.0141
	6.41 (0.006)[g]	37.93 (0.000)[g]	56.83 (0.000)[g]
U.K.	0.0094	0.0087	0.0100
	0.0120	0.0107	0.0098
	3.24 (0.078)[e]	5.21 (0.021)[f]	0.26 (0.613)
U.S.	0.0089	0.0085	0.0095
	0.0074	0.0108	0.0092
	1.50 (0.234)	8.32 (0.004)[g]	0.82 (0.367)

[a]Standard deviation before.
[b]Standard deviation after.
[c]Modified Levene value.
[d]Bootstrap marginal significance level.
[e]Significant at the 10% level.
[f]Significant at the 5% level.
[g]Significant at the 1% level.

matched electronically. Japan also operates as a continuous trading market, but uses *Zaraba*, a method of open outcry. To match orders, the stock exchanges in the U.S.

and the U.K. operate as continuous trading markets where specialists (jobbers in the U.K.) and dealers act as marketmakers.

Price stabilization mechanisms also may affect stock volatility. Australia and Hong Kong have no price stabilization mechanism. In the U.S. specialists have an affirmative obligation to provide continuous quotes. In the U.K. jobbers compete. In Japan there is a price change limit (20%) to stabilize stock prices. There are numerous other differences in the market structure of the individual countries which may impact stock volatility.

To control for the effects of other determinants of volatility, i.e., to capture the impact of only the stock index futures listing on return volatility, international portfolios are constructed of the stock indices of the five stock markets, centered on the stock index futures listing date of each market. That is, a compilation is made of returns of a portfolio made up by investors who buy a stock index in each stock market on the kth business day before the stock index futures listing and subsequently sell the stock index $2k$ business days later ($k = 100, 250, 500$). Then the return volatilities of the portfolio made up by these investors are compared for the two subperiods before and after the start of trade in stock index futures to see whether they differ significantly. If they differ, the reason would be the presence of the stock index futures market. This procedure can be classified as an *event study* methodology.

Table III shows market capitalization in $U.S. billions and a ratio of total market capitalization of each stock market as of April 28, 1989.

An equally weighted international portfolio and a value weighted international portfolio are constructed using the ratios of total market capitalization. Table IV contains the standard deviations of the two international portfolios before and after index futures listing, the modified Levene values, and the corresponding bootstrap marginal significance levels. The estimated modified Levene values indicate that return volatilities in both the value weighted portfolio and the equally weighted portfolio increase significantly, which supports the destabilization hypothesis. This evidence also helps explain what causes stock return volatility to change over time.

The size of the change in the volatility measure and the magnitude of the test statistic are smaller for the equally weighted portfolio compared to the value weighted portfolio. The probability of no significant difference in volatility before and after the introduction of futures trading is higher in the equally weighted portfolio. These numbers indicate that a strong volatility effect in Japan may be driving the portfolio results. To investigate this possibility, the analysis is repeated, omitting one country at a time.

Table V shows the standard deviations of international portfolio returns omitting one country and the corresponding modified Levene values. In the short test interval,

Table III
MARKET CAPITALIZATION IN $U.S. BILLIONS AS OF APRIL 28, 1989[a]

	Australia	Hong Kong	Japan	U.K.	U.S.	Sum
$U.S. billions	125.9	86.8	3783.9	771.3	2709.0	7476.9
Ratio[b]	0.0168	0.0116	0.5061	0.1032	0.3623	1.0

[a]Source: Nomura Investment Review (June 1989).
[b]Ratio is used to construct the international value weighted portfolio.

the Levene values show that the volatilities of value weighted portfolios increase, excluding the portfolios omitting Japan and the U.K. Also, among the equally weighted portfolios, the volatility of only the portfolio omitting Hong Kong increases significantly. In the intermediate test interval, the volatilities of both of the value weighted portfolios and the equally weighted omitting one country at a time increases after the introduction of index futures. In the long test interval, only the portfolio omitting Japan in both the value weighted and the equally weighted shows no significant difference in the volatility before and after the listing. These indicate that a strong volatility effect in Japan is largely driving the portfolio results, while the effects in the other countries, excluding Hong Kong, are slightly driving the portfolio results in the short test interval only.

Structural Change in Time-Varying Volatility

The switching GARCH model is used to test whether changes in the mean level and the autoregressive structure of volatility occur around the time of the stock index futures listing. Nonlinear optimization techniques are used to calculate the maximum likelihood estimates based on the BHHH algorithm.[9] The descriptive validity of the estimated model can be evaluated with a likelihood ratio (LR) statistic that is asymptotically distributed as a chi-square random variable with k degrees of freedom equaling the difference in the number or parameters under the null and alternative hypothesis. The null hypothesis is rejected if the value of the test statistic, LR, is too large, i.e., when LR $\geq \chi_k^2$ distribution.[10]

[9]See Berndt, et al. (1974). Initial values must be chosen in using this estimation method. The estimated coefficients of French, Schwert, and Stambaugh (1987) are used as the initial values for the GARCH coefficients. Initial values of coefficients with dummy variables are zero. The convergence criteria used in adopting the BHHH approach are 10^{-4} in θ, γ_1, α_1, γ_{1d}, α_{1d}, and 10^{-5} in β_0, γ_0, γ_{0d}.

[10]The GARCH model with the MA(1) process is used using 1000 daily returns of two portfolios. The primary purpose of this initial estimation is to evaluate the descriptive validity of the GARCH model and to test whether stock return volatility changes over time. For the value weighed portfolio, the following is obtained:

$$\underset{}{R_t} = \underset{(3.30)}{0.00057} + \epsilon_t + \underset{(-5.46)}{0.2324\epsilon_{t-1}}$$

$$\sigma_t^2 = \underset{(16.52)}{0.000012} + \underset{(11.45)}{0.3036\sigma_{t-1}^2} + \underset{(39.00)}{0.4965\epsilon_{t-1}^2}, \quad \text{LR statistic} = 226.62$$

For the equally weighted portfolio, the following is obtained:

$$R_t = \underset{(3.86)}{0.00060} + \epsilon_t + \underset{(-3.29)}{0.1347\epsilon_{t-1}}$$

$$\sigma_t^2 = \underset{(15.87)}{0.000011} + \underset{(10.43)}{0.3023\sigma_{t-1}^2} + \underset{(29.34)}{0.3704\epsilon_{t-1}^2}, \quad \text{LR statistic} = 208.48$$

Numbers in parentheses are t-values. Results show that the coefficients indicating the autoregressive structure of returns (α_1, γ_1) are significantly positive, implying that conditional volatility of portfolio returns change over time (heteroskedastic). The LR statistics in two portfolio return cases are very large, which means that the GARCH model is an attractive representation of daily stock return behavior, successfully capturing the temporal dependence of return volatility. Estimating the GARCH model with the MA(1) process produces a significant negative sign in the MA(1) coefficient θ in both the value weighted portfolio returns and the equally weighted returns. This means that portfolio returns composed of stock indices' returns show positive serial correlation. These results confirm those obtained by many researchers who have examined the time-varying volatility of stock returns.

Table IV
STOCK RETURN VOLATILITY BEFORE AND AFTER INDEX FUTURES LISTING: INTERNATIONAL PORTFOLIO'S CASE

	Est. Int.		
Portfolio	**−/ + 100**	**−/ + 250**	**−/ + 500**
Value weighted	0.0057[a]	0.0049	0.0049
	0.0071[b]	0.0074	0.0080
	3.11[c](0.086)[d,e]	29.37 (0.000)[g]	26.62 (0.000)[g]
Equally weighted	0.0042	0.0041	0.0047
	0.0050	0.0051	0.0066
	2.80 (0.096)[e]	10.50 (0.002)[f]	5.18 (0.022)[f]

[a]Standard deviation before.
[b]Standard deviation after.
[c]Modified Levene value.
[d]Bootstrap marginal significance level.
[e]Significant at the 10% level.
[f]Significant at the 5% level.
[g]Significant at the 1% level.

The switching GARCH model is used to test whether the structural change in time-varying volatility (autoregressive structure of volatility) occurs after the listing.[11] As reported in Table VI, in both the value weighted portfolio returns and the equally weighted portfolio returns, there are noticeable differences in the autoregressive structure as well as in the mean level of the conditional volatility process for periods before and after the index futures listing. This indicates that substantial changes in market efficiency occur after the listing. The γ_{0d} coefficient, indicating the change in the level of volatility, increases significantly, implying that the mean level of volatility increases after the stock index futures listing. This result confirms the previous result obtained by using the modified Levene test. The α_{1d} coefficient indicating the structural change in the first autoregressive structure of the squared residuals of portfolio returns is significantly positive, while the γ_{1d} coefficient indicating the structural change in the effect of σ^2_{t-1} conditional volatility at time $t - 1$ on σ^2_t at

[11]The switching GARCH analysis is performed on each individual country's series of returns, but the GARCH model fails to converge with the exception of Australia and Japan. Detailed explanations for the convergence of the ARCH family are documented in Engle et al. (1987). For stock return series in Australia:

$$R_t = \underset{(1.29)}{0.00036} + \epsilon_t + \underset{(-8.14)}{0.3119\epsilon_{t-1}}$$

$$\sigma^2_t = \underset{(8.08)}{0.000002} + \underset{(31.17)}{0.8370\sigma^2_{t-1}} + \underset{(4.96)}{0.1882\epsilon^2_{t-1}} + \underset{(11.87)}{0.000044 D_t} - \underset{(-14.71)}{0.6544\sigma^2_{t-1} D_t} + \underset{(1.74)}{0.0964\epsilon^2_{t-1} D_t}$$

LR statistic = 53.76.

For stock return series in Japan:

$$R_t = \underset{(4.24)}{0.00085} + \epsilon_t + \underset{(-7.18)}{0.3104\epsilon_{t-1}}$$

$$\sigma^2_t = \underset{(7.85)}{0.000009} + \underset{(14.10)}{0.3825\sigma^2_{t-1}} + \underset{(11.99)}{0.3836\epsilon^2_{t-1}} + \underset{(6.19)}{0.000025 D_t} - \underset{(-4.78)}{0.1619\sigma^2_{t-1} D_t} + \underset{(9.87)}{0.3870\epsilon^2_{t-1} D_t}$$

LR statistic = 713.91.

Table V
STOCK RETURN VOLATILITY BEFORE AND AFTER INDEX FUTURES LISTING: INTERNATIONAL PORTFOLIO'S CASES EXCLUDING ONE COUNTRY

Country Excluded	Est. Int. −/+ 100	Est. Int. −/+ 250	Est. Int. −/+ 500
Value weighted			
Australia	0.0059[a]	0.0050	0.0049
	0.0071[b]	0.0075	0.0081
	3.13[c](0.077)[d,e]	29.19 (0.000)[g]	27.20 (0.000)[g]
Hong Kong	0.0059	0.0050	0.0049
	0.0071	0.0075	0.0081
	3.17 (0.076)[e]	29.60 (0.000)[g]	26.93 (0.000)[g]
Japan	0.0068	0.0064	0.0074
	0.0060	0.0084	0.0072
	0.02 (0.872)	11.19 (0.000)[g]	0.70 (0.414)
U.K.	0.0063	0.0054	0.0053
	0.0078	0.0081	0.0088
	3.61 (0.060)	26.98 (0.000)[g]	27.68 (0.000)[g]
U.S.	0.0071	0.0059	0.0054
	0.0097	0.0098	0.0114
	4.87 (0.028)[f]	39.29 (0.000)[g]	57.12 (0.000)[g]
Equally weighted			
Australia	0.0051	0.0048	0.0055
	0.0053	0.0058	0.0078
	1.05 (0.303)	9.64 (0.000)[g]	5.11 (0.023)[f]
Hong Kong	0.0045	0.0040	0.0044
	0.0056	0.0058	0.0056
	5.51 (0.019)[f]	27.87 (0.000)[g]	13.66 (0.000)[g]
Japan	0.0045	0.0048	0.0056
	0.0050	0.0055	0.0074
	1.46 (0.222)	3.09 (0.079)[e]	0.28 (0.610)
U.K.	0.0049	0.0049	0.0054
	0.0057	0.0058	0.0078
	1.46 (0.222)	6.08 (0.016)[f]	5.47 (0.019)[f]
U.S.	0.0051	0.0050	0.0055
	0.0057	0.0059	0.0078
	1.06 (0.302)	5.90 (0.016)[f]	5.83 (0.017)[f]

[a]Standard deviation before.
[b]Standard deviation after.
[c]Modified Levene value.
[d]Bootstrap marginal significance level.
[e]Significant at the 10% level.
[f]Significant at the 5% level.
[g]Significant at the 1% level.

time t is significantly negative. Indeed, empirical evidence suggests that the presence of the stock index futures market causes drastic structural change in the autoregressive structures as well as in the mean level of stock return volatility.

Table VI
INDEX FUTURES LISTING AND STRUCTURAL CHANGE IN TIME-VARYING VOLATILITY

	Portfolio			
	Value Weighted		Equally Weighted	
Parameter	Coeff.	t-Stat.	Coeff.	t-Stat.
$\beta_0(\times 10^2)$	0.0595	3.54	0.0609	3.94
θ	−0.2193	−5.49	−0.1199	−3.06
$\gamma_{0b}(\times 10^4)$	0.0809	9.16	0.0731	9.51
γ_{1b}	0.4825	16.54	0.5437	18.23
α_{1b}	0.1622	7.95	0.1228	6.32
$\gamma_{0d}(\times 10^4)$	0.1033	7.64	0.0697	6.26
γ_{1d}	−0.2565	−7.45	−0.3539	−9.75
α_{1d}	0.4920	21.82	0.4198	17.23
LR statistic	270.24		229.52	

t-Statistic is about 1.645, 1.960, and 2.326 at 10%, 5%, and 1% level, respectively.
χ^2_6 Critical value is 10.64, 12.59, and 16.81 at 10%, 5%, and 1% level, respectively.

In the GARCH model, σ^2_{t-1}, conditional volatility at time $t - 1$, is a function of $\epsilon^2_{t-2}, \epsilon^2_{t-3}, \ldots$, squared residuals after the first lag. Results in Table VI show that the α_{1d} coefficient, indicating the structural change in the first autoregressive structure of squared residuals of portfolio returns, is significantly positive, while the γ_{1d} coefficient, indicating the change in the autoregressive structure of their squared residuals after the first lag, is significantly negative. That is, after the stock index futures listing, the effect of ϵ^2_{t-1} on σ^2_t relatively increases, but the effect of σ^2_{t-1} on σ^2_t relatively decreases in comparison with those of the period before listing. This implies that volatility shocks are more quickly digested and reflected in the stock market after the index futures listing. Therefore, although the creation of stock index futures on the whole exerts a volatility-increasing influence on the behavior of daily cash stock returns, it makes the stock market relatively more *efficient* because volatility shocks (information packets) are more quickly assimilated in that market.

Furthermore, the switching GARCH analysis is performed on portfolios omitting one country at a time to examine whether the effect in one country is driving the portfolio results.[12] The size of coefficients and the magnitude of t-values in Table VII are similar to those of Table VI, thereby indicating that the stock market becomes relatively more *efficient* because volatility shocks are more quickly assimilated in that market after the introduction of the stock index futures. The slight difference between these results and the previous results is that, in the equally weighted portfolio omitting Japan, the size of α_{1d} coefficient indicating the structural change in the first autoregressive structure of volatility becomes remarkably smaller. This, however, does not affect the result that the stock market becomes relatively more *efficient* after the introduction of the stock index futures.

[12]The switching GARCH analysis is performed on the portfolios omitting one country, but the GARCH model fails to converge for the value weighted portfolio omitting Japan and the equally weighted portfolio omitting Hong Kong.

Table VII
INDEX FUTURES LISTING AND STRUCTURAL CHANGE IN TIME-VARYING VOLATILITY: INTERNATIONAL PORTFOLIO'S CASES EXCLUDING ONE COUNTRY

Value Weighted International Portfolio				
Country Excluded	Australia	Hong Kong	U.K.	U.S.
$\beta_0(\times 10^2)$	0.0612 (3.63)	0.0591 (3.47)	0.0561 (3.07)	0.0793 (4.42)
θ	−0.2238 (−5.60)	−0.2191 (−5.48)	−0.2238 (−5.80)	−0.2995 (−6.69)
$\gamma_{0b}(\times 10^4)$	0.0786 (8.75)	0.0831 (9.24)	0.0768 (7.20)	0.0514 (5.68)
γ_{1b}	0.4945 (16.86)	0.4761 (16.63)	0.5927 (20.21)	0.4607 (16.11)
α_{1b}	0.1618 (7.96)	0.1665 (8.18)	0.1194 (5.75)	0.3667 (11.33)
$\gamma_{0d}(\times 10^4)$	0.1058 (7.56)	0.1091 (7.97)	0.1203 (6.58)	0.1502 (5.36)
γ_{1d}	−0.2668 (−7.70)	−0.2508 (−7.48)	−0.3340 (−9.49)	−0.2027 (−5.84)
α_{1d}	0.4986 (22.15)	0.4839 (21.54)	0.5232 (22.73)	0.4600 (11.86)
LR statistic	279.72	268.06	288.46	617.91

Equally Weighted International Portfolio

Country Excluded	Australia	Japan	U.K.	U.S.
$\beta_0(\times 10^2)$	0.0732 (4.12)	0.0565 (3.23)	0.0511 (3.05)	0.0690 (3.87)
θ	−0.1209 (−3.07)	−0.1191 (−3.15)	−0.1528 (−5.41)	−0.0998 (−2.53)
$\gamma_{0b}(\times 10^4)$	0.1033 (11.50)	0.0992 (11.51)	0.0726 (7.24)	0.0833 (7.49)
γ_{1b}	0.5211 (19.52)	0.5443 (18.85)	0.6837 (22.44)	0.6230 (20.89)
α_{1b}	0.1244 (6.26)	0.1371 (7.00)	0.0719 (4.40)	0.0932 (5.12)
$\gamma_{0d}(\times 10^4)$	0.1167 (9.83)	0.1500 (14.01)	0.1079 (7.42)	0.0905 (4.92)
γ_{1d}	−0.4172 (−13.37)	−0.5117 (−14.66)	−0.5188 (−13.45)	−0.4540 (−12.00)
α_{1d}	0.4484 (17.25)	0.1769 (7.27)	0.4655 (24.68)	0.5232 (22.73)
LR statistic	276.85	303.00	267.73	249.25

Note: Numbers in parentheses are t-statistics.

t-Statistic is about 1.645, 1.960, and 2.326 at 10%, 5%, and 1% levels, respectively.

CONCLUSIONS

This study documents the effect of the start of trade in stock index futures on cash stock market volatility and market efficiency. It is found that stock market volatility increases significantly after the stock index futures are listed on the underlying index, with the exception of the Australian and the Hong Kong stock markets. In Australia, no significant difference exists in stock market return volatility for subperiods before and after the index futures listing. In the short test interval, the stock return volatility decreases in Hong Kong.

Also, two international portfolios composed of five stock markets' indices are constructed to control for the other determinants of volatility, such as country-specific financial and economic factors and worldwide factors. This study shows that the portfolio return volatility increases significantly after the listing of stock index futures.

Furthermore, it is found that, although the creation of stock index futures exerts a volatility-increasing influence on daily cash stock price behavior, it makes the stock market relatively more *efficient* as volatility shocks (information packets) are more quickly assimilated in that market.

Bibliography

Akgiray, V. (1989): "Conditional Heteroskedasticity in Time Series of Stock Returns: Evidence and Forecasts," *Journal of Business,* 62:55–80.

Amihud, Y., and Mendelson, H. (1987): "Trading Mechanisms and Stock Returns: An Empirical Investigation," *Journal of Finance,* 42:533–555.

Amihud, Y., Mendelson, H., and Murgia, M. (1990): "Stock Market Microstructure and Return Volatility: Evidence from Italy," *Journal of Banking and Finance,* 14:423–440.

Baillie, R.T., and DeGennaro, R.P. (1990): "Stock Returns and Volatility," *Journal of Financial and Quantitative Analysis,* 25:203–214.

Bera, A.K., and Jarque, C.M. (1981): "An Efficient Large-Sample Test for Normality of Observations and Regression Residuals," Working Papers in Econometrics 40, Australian National University, Canberra.

Berndt, E.K., Hall, B.H., Hall, R.E., and Hausman, J.A. (1974): "Estimation and Inference in Nonlinear Structural Models," *Annals of Economic and Social Measurement,* 4:653–665.

Bollerslev, T. (1986): "Generalized Autoregressive Conditional Heteroskedasticity," *Journal of Econometrics,* 31:307–327.

Bollerslev, T. (1987): "A Conditional Heteroskedastic Time Series Model for Speculative Prices and Rates of Return," *Review of Economics and Statistics,* 69:542–547.

Bortz, G.A. (1984): "Does the Treasury Bond Futures Market Destabilize the Treasury Bond Cash Market?" *The Journal of Futures Markets,* 4:25–38.

Brown, M.B., and Forsythe, A.B. (1974): "Robust Tests for the Equality of Variance," *Journal of the American Statistical Association,* 69:364–367.

Cohen, K., Hawawini, G., Maier, S., Schwartz, R., and Whitcomb, D. (1980): "Implications of Microstructure Theory for Empirical Research on Stock Price Behavior," *Journal of Finance,* 35:249–257.

Cohen, K., Maier, S., Schwartz, R., and Whitcomb, D. (1986): *The Microstructure of Security Markets.* Englewood Cliffs, NJ: Prentice-Hall.

Edwards, F.R. (1988a): "Futures Trading and Cash Market Volatility: Stock Index and Interest Rates Futures," *The Journal of Futures Markets,* 8:421–439.

Edwards, F. R. (1988b): "Does Futures Trading Increase Stock Market Volatility?" *Financial Analysts Journal,* 44:63–69.

Efron, B. (1982): *The Jackknife, the Bootstrap and Other Resampling Plans.* Philadelphia: Society for Industrial and Applied Mathematics.

Ely, D. (1988): "Costs of Risk Shifting and Cash Market Stability," Working Paper, Department of Finance, San Diego State University, San Diego, CA.

Engle, R. F. (1982): "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica,* 50:987–1007.

Engle, R. F., Lilien, D. M., and Robins, R. P. (1987): "Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model," *Econometrica,* 55:391–407.

French, K. R., and Roll, R. (1986): "Stock Return Variances: The Arrival of Information and the Reaction of Traders," *Journal of Financial Economics,* 17:5–26.

French, K. R., Schwert, G. W., and Stambaugh, R. F. (1987): "Expected Stock Returns and Volatility," *Journal of Financial Economics,* 19:3–29.

Friedman, M. (1953): *The Case of Flexible Exchange Rates, Essays in Positive Economics.* Chicago: University of Chicago Press.

Herbst, A., McCormack, J. P., and West, E. N. (1987): "Investigation of a Lead-Lag Relationship Between Spot Stock Indices and Their Futures Contracts," *The Journal of Futures Markets,* 7:373–381.

Kawaller, G. I., Koch, P. D., and Koch, T. W. (1990): "Intraday Relationship Between Volatility in S&P 500 Futures and Volatility in the S&P 500 Index," *Journal of Banking and Finance,* 14:373–397.

Layard, M. W. J. (1973): "Robust Large-Sample Tests for Homogeneity of Variances," *Journal of the American Statistical Association,* 68:195–198.

Lee, S. B., and Ohk, K. Y. (1991): "Time-Varying Volatilities and Stock Market Returns: International Evidence," *Pacific-Basin Capital Markets Research,* 2:261–281.

Levene, H. (1960): "Robust Tests for Equality of Variances," in *Contributions to Probability and Statistics,* Olkin, I. (ed.). Palo Alto, CA: Stanford University Press.

Lockwood, L. J., and Linn, S. C. (1990): "An Examination of Stock Market Return Volatility During Overnight and Intraday Periods, 1964–1989," *Journal of Finance,* 45:591–601.

Miller, M. H. (1991): "Volatility, Episodic Volatility and Coordinated Circuit-Breakers," *Pacific-Basin Capital Markets Research,* 2:23–47.

Pindyck, R. S. (1984): "Risk, Inflation, and the Stock Market," *American Economic Review,* 74:335–351.

Poterba, J. M., and Summers, L. H. (1986): "The Persistence of Volatility and Stock Market Fluctuations," *American Economic Review,* 76:1142–1151.

Scholes, M., and Williams, J. (1977): "Estimating Betas from Nonsynchronous Data," *Journal of Financial Economics,* 5:309–327.

Simpson, W., and Ireland, T. (1982): "The Effect of Futures Trading on the Price Volatility of GNMA Securities," *The Journal of Futures Markets,* 2:357–364.

Simpson, W. (1985): "The Impact of Financial Futures on the Cash Market for Treasury Bills," *Journal of Financial and Quantitative Analysis,* 20:371–379.

Stoll, H. R., and Whaley, R. E. (1987): "Expiration Day Effects of Index Options and Futures," *Financial Analysts Journal,* 43:16–28.

Weller, P., and Yano, M. (1987): "Forward Exchange, Futures Trading, and Spot Price Variability: A General Equilibrium Approach," *Econometrica,* 55:1433–1450.

Zeckhauser, R., and Niederhoffer, V. (1983): "The Performance of Market Index Futures Contracts," *Financial Analysts Journal,* 39:59–65.