Business and Economics Journal

Jarrett et al., Bus Eco J 2017, 8:1
DOI: 10.4172/2151-6219.1000283

Research Article Open Access

Asian Equity Markets: A Time Series Analysis of their Co-integration

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Abstract

This research examines the time series characteristics of stock price indices for Hong Kong, Tokyo and Singapore Equity Markets or stock exchanges during the lengthy period from before 1997, 1997 to 2007 and after 2007. Specifically, we calculate the rate of return and the volatility of return for all three markets and estimate co-movement of the three markets. We find that the average rate of return varies dramatically for the three equity markets and across time. Further, we find that stock prices are positively serially correlated in general. In the multivariate regressions, we find that there is little evidence to show that either the rate of return in certain markets universally affects the rate of return in other equity markets. We suggest based on the evidence that the three markets are co-integrated but not universally across time and with each other in pairwise dimensions. Lastly, we studied and made conclusions concerning the mean and variation in the volatility of the rates of return in the three equity markets studied.

Keywords: Time series; Financial indices; Volatility; Correlation; Hang Seng; Tokyo and Singapore equity markets

Introduction

We study three sets of weekly price indices; Tokyo Composite Index, the Hang Seng (Hong Kong Stock Exchange Composite Index) and the Singapore Exchange provided by common data collected during a lengthy period of time. Studies of these data are important because of the rapid growth and influence of the Asian and especially the Pacific Basin economies on the world, balance of trade and growth of Asian and other economies throughout the world [1-3]. Previous studies [4-6] described China as an economic power offering tremendous opportunities for investment and growing business returns. Their financial markets for the earlier years in their development were thought not to be fully developed when analyzed by the criteria developed by financial economists using criteria for analyzing Western equity markets [7-10]. Chow and Lawler [11], and later, Jarrett and Sun [12], analyzed the price index for the Shanghai Stock Exchange in comparison with the New York Stock Exchange Index in terms of its rate of return, volatility and structural changes in the movement of the index; also Jarrett, Kyper and Klein [13] studied relationships between large Asian and the New York and London exchanges In this study, we propose to analyze the entire period from January 1991 to December 2012 dividing the period into sub periods (sub samples) to analyze change associated with time and especially significant economic events. The comparisons have the purpose of revealing the behavior of stock movements in an emerging market in comparison with an established Western market. Previous studies by Bailey et al. [14], Jarrett and Sun [2,3], Jarrett and Kyper [15] focused on other issues in Chinese equity markets. We will now focus on three non-Chinese of the largest Asian equity markets because they are central areas of trade and economic activities not expressed only in the Shanghai equity market of China. Although previous studies show that Asian markets became and continue to integrate themselves with other and small Asian equity exchanges (note CMP and [12].

We will assess the degree of integration of the three Asian equity markets to determine how they affect each other independent of the large global markets in China (PRC), The United States and London Correlations among the markets determined among the markets will give rise to the integration of these markets and evidence will be shown of these factors. As well as the association .with the rest of the world as represented by the movement of prices in the New York Stock Exchange (NYSE). We will also look at the correlations among the Shanghai, NYSE and Hong Kong markets (Hang Seng Index) to examine their integration as well.

We examine both the rate of return and the volatility of the price indexes. The rate of return is the change in the natural logarithm of the price index for a given time period. We follow Chow and Lawler [11] and Jarrett and Sun [12], hereafter, JS, Jarrett, Klein and Kyper, hereafter JKK) in measuring the volatility by the absolute value of the change rather than by its variance. The absolute value is less sensitive to extreme value as compared with ARCH-type models to study the residual variance of a time series model. Stated differently, we study the volatility of the rate of return itself and not the residual in the time series model of the rate of return. Following CL, JS and JKK; (1) the volatility in the rate of return and not the time series regression model residual is the subject of interest in financial research and (2), "since log stock price behaves approximately like a random walk, the rate of return itself and the residual of an auto regression of this rate are almost the same." The data for this study include four sets of weekly price indices of the three Asian markets noted before. The rate of return is calculated as the change in the natural logarithm of the price index in a given period. The volatility of returns is calculated as the absolute value of the change in the natural logarithm of the price index in a given period. We further divide our sample into three subsamples: before 1997, after 1997 and before 2007, and after 2007. The entire sample period is from October 1987 to through 2012. Both 1997 and 2007 are years in which the economic environment changed. In turn this affected the world's equity markets. Hence, we separated the data into three sub-time-periods. Lastly, we follow CL, JS and JKK in choosing the weekly data as the best choice among daily, weekly and monthly data.

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Received January 17, 2017; **Accepted** January 23, 2017; **Published** January 28, 2017

Citation: Jarrett JE, Kyper E, Prante G (2017) Asian Equity Markets: A Time Series Analysis of their Co-integration. Bus Eco J 8: 283. doi: 10.4172/2151-6219.1000283

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To begin, we examine the measure of volatility. If botcharacteristics of the equity markets. We calculate the mean and variance of the rate of return and the mean and variance of the meh these measures reflect uncertainty, the volatility in Asian stock prices should be more volatile than those in New York. To study the co-movements of the price in the two markets, we calculate simple correlations and multiple regressions. The multiple regressions include auto regressions as well as ordinary multiple regressions. There was no rational reason to examine curvilinear models since the study of residuals did not indicate nonlinearity in relationships. The remainder of this paper is organized as follows: (1) the characteristics of the rate of return and the volatility of return; (2) correlation coefficients; (3) regressions of the rate of return; (4) regressions of the volatility of return; and (5) conclusions.

Rate of return and volatility of Hong Kong, Tokyo and Singapore stock indices

Table 1 shows the information for the Hong Kong, Tokyo, and Singapore stock price indexes including the market capitalization and the number of listed stocks. The sizes of the three financial markets indicate that the Tokyo equity market is much larger than the other two equity markets in terms of both market capitalization and the number of listings. In terms of market capitalization per listing, Tokyo is also highest at over $2 billion per listing, followed by Hong Kong ($1.5 billion per listing) and Singapore ($1.3 billion per listing). There is a rich literature on the relationship between market listings and the size of the economy Levine and Zervos [16]. For a summary of current discussion on this topic see Levine [17].

Table 2 shows the means and standard deviations (variation) of the rates of return for the three equity markets, while Table 3 presents the means and standard deviations of the volatility of returns in the same three markets. For Table 2, the means are highest for Hang Seng followed by Singapore and Tokyo, which is close to zero in the time period analyzed. The standard deviation is highest for Hang Seng followed by Tokyo and Singapore which are very close. In JKK, we observed that the variations in the Asian markets were greater than in the Western markets (New York and London).

In regards to the volatility in the rates of return for the same three equity markets we observe the Hang Seng equity market has the greatest volatility (Table 3). The variation (standard deviation) in volatility is again larger in the Hang Seng market than the others. The Tokyo market's standard deviation is smaller than the two other Asian markets. Statistical tests of significance (not reported here) results in rejecting the hypothesis of no difference between the Tokyo and the other markets.

Stock exchange	Market capitalization (US$ billion)	Number of listings
Hang Seng (Hong Kong)	2,314.29	1,548
Nikkei 225 (Tokyo)	5,063.80	2,431
STI (Singapore)	969.46	770

Table 1: Size of three Asian markets.

Stock exchange (index)	Hong Kong (Hang Seng)	Tokyo (Nikkei)	Singapore (STI)
Mean	0.0022	0.0004	0.0014
Standard Deviation	0.0334	0.0296	0.0284

Table 2: Mean and standard deviations in rates of returns.

Stock exchange (index)	Hong Kong (Hang Seng)	Tokyo (Nikkei)	Singapore (STI)
Mean	0.0249	0.0223	0.0195
Standard Deviation	0.0223	0.0195	0.0206

Table 3: Mean and standard deviations in volatility of returns.

The mean rate of return for Hang Seng (0.0022) is about five times larger than the mean rates of return for Tokyo (0.0004) and nearly double that of Singapore (0.0014). Thus, the Hang Seng Index is growing at a rate much larger than the other equity markets. All three of them represent developed economies whereas Hang Seng, while not underdeveloped, is greatly influenced by the dynamics of the Chinese equity market and economy due to shares being cross-listed with the Shanghai stock exchanges. If we were to consider change in price levels for the two nations by examining data on the consumer price indexes for the three nations (although not a perfect comparison), the changes in prices would not account for the major portion of the differences in the average rates of return. This leads to a conclusion that the greater mean rate of return for the Hang Seng Index is not attributable to factors other than the investment opportunities in its market and the influence of dual-listed equities with those of China [18].

Volatility (as noted before) as measured by both the standard deviation of the rate of return and by the mean volatility in the rate of return is larger for the Hang Seng stock market than for the two alternative markets. Table 2 shows a larger variation for the Hang Seng stock index than for the others. Table 3 concurs by showing a larger mean volatility of return for Hang Seng as well. This suggests a great deal of uncertainty in the Hang Seng market in comparison to the other markets. Furthermore, the standard deviation of the measure in Table 3 is also greater for Hang Seng than it is for the other equity markets. These results are not a revelation and are similar as those of CL, JK and JKK. This would lead one to observe that the volatility is subject to a greater degree of variation; that is, the spread in the distribution in Hang Seng is greater than the distribution for the other three markets. Again, this is consistent with the previous findings by CL, JS and JKK. This is not to say that volatility does not exist or is even small in the other markets, but only to say that a risk-averse investor is better served by the developed market of Tokyo rather than the others.

To test how the three equity markets behave during extreme events, we sort sample period to three economic sub-periods and examine the mean and volatility of the rate of return during these periods: (1) 1987 through the last week of 1996; (2) 1997 to the end of 2007; and (3) after 2007 until the end of the sample data period. By studying these three periods, one may determine if severe economic changes occurring in 1997 and 2007 affect the three markets and whether the changes differ.

We find a downward change in the mean rate of return for Hang Seng from period 1 to period 2 and again in period 3 as reported in Table 4, Panel A. The mean rate of return for Tokyo slightly increases similar in periods 1 and 2 and from period 2 to 3. For Singapore, the mean rate decreased from period 1 to period 3. After 2007, the declines are very evident in Hang Seng and Singapore but not in Tokyo.

In studying variation, we observe the standard deviations of the rates of return are largest for the Hang Seng Index. In all three time periods the Tokyo exchange had the second largest variation in rates of return but not nearly as large as that for the Hang Seng market. For Singapore, the mean rate decreased from period 1 to period 2 and again for period 2 to period 3. After 2007, the declines are very evident in Hang Seng and Singapore but not in Tokyo.

In studying variation, we observe the standard deviation of the rates of return for the Hang Seng Index are virtually equal to Tokyo in Period 3. In all time periods, the Tokyo Exchange exhibited the second largest variation in period 1, smallest in period 2 and tied for greatest in period 3. Singapore variation grew between periods 1 and 2 and declined in period 3.

In Table 4, Panel B, we observe changes in the mean and variation in the volatility of the rates of return for the equity across periods 1 and 2, but not in 3. The mean volatility in the rates of return for the markets did not change substantially in the three periods. The order in terms of size of mean did not change during the sub-periods. Hang Seng had the largest mean, followed by Tokyo and Singapore. For variation in volatility, the standard deviation across all time periods indicated the same variation in order for all three periods and for all equity markets (exchanges).

In summary, the results demonstrate that there are temporal relationships between mean rates of return and mean volatility in the rates of return as well as variation in both mean and volatility in the rates of return for these data studied. This knowledge makes it very difficult to produce forecasts (especially medium and long-term duration) of the mean and variability for the three equity markets. Further, the analysis does not dispute studies in the past such as CL, JK and JKK. Nevertheless, this new study does bring to light the difficulties of grouping Asian markets into a singular category. These analyses produce corroborating evidence of previous studies that indicate a necessary understanding of the permanent and temporary components of time series market characteristics. Ray, Jarrett and Chen [19] indicated for the Tokyo stock exchange that such components existed, but studies of this type need to be replicated for Tokyo as well as other markets.

The economic change occurring in the world during the three time periods kept the three markets more volatile and often more profitable than the ones in more established markets. Risk-averse investors were better off in more established markets because of the smaller level of volatility but they are giving up some possibility of higher return. For Tokyo, the differences in the sample statistics for the three time periods suggest that the rates of return and volatility in stock prices in nominal terms for the entire time period studied were not covariate stationary time series. This is the same conclusion for a much larger time period than observed by CL and JS. Their conclusions at this point are not disputed but only enhanced by the study of the new and expanded analysis of these three markets. Tokyo, the largest of the three markets under study, achieved wide variation even though it is much larger than the other two. If we had included one or more of the China (PRC) stock exchanges, the variability of Tokyo may not seem as large. This notion is for another study but may indicate that largeness is not a protection from risk. Tokyo, the largest, may appear more risk-averse than the others due to its size, but it has the greatest level of temporal volatility which could yield short-term gains but still may not be the best place to invest over a longer extended period. Singapore may have other possibilities with some extensions. Additional study of this market may yield additional possibilities. Lastly, grouping smaller Asian markets together may not be a wise choice for researchers as well as portfolio managers.

Panel A: Rate of return	Hang Seng	Nikkei	STI
Before 1997			
Mean	0.0042	-0.0002	0.0024
Standard Deviation	0.0310	0.0280	0.0232
1997-2007			
Mean	0.0019	0.0001	0.0013
Standard deviation	0.0355	0.0284	0.0327
After 2007			
Mean	0.0003	0.0014	0.0003
Standard Deviation	0.0330	0.0331	0.0271
Panel B: Volatility of return	**Hang Seng**	**Nikkei**	**STI**
Before 1997			
Mean	0.0233	0.0204	0.0174
Standard Deviation	0.0209	0.0191	0.0156
1997-2007			
Mean	0.0264	0.0225	0.0223
Standard Deviation	0.0237	0.0174	0.0239
After 2007			
Mean	0.0248	0.0244	0.0180
Standard Deviation	0.0217	0.0225	0.0202

Table 4: Rate of return and volatility in three subsamples of time (Asian markets).

The correlation in price movements

Up to now, we focused on one developed Asian market and two smaller developing Asian markets and the studies of CL, JS and JKK, and we ascertained a preliminary view of the level of integration among the Tokyo, Hang Seng and Singapore markets. By calculating and examining the Pearson Product Moment linear correlation coefficients, we can ascertain the strength of the relationships, as presented in Table 5 below. All data came from known public sources. Note that the Hang Seng and Nikkei (Tokyo) for the rate of return (Panel A) have a correlation of 0.4307, indicating that less 19% of the variation in the first market explains the variation in the other market. The same Pearson coefficient for Hang Seng and Singapore is 0.6637, which indicates that about 44% of the variation in one index is explained by the variation in the other index. A similar result occurs for the association of the Singapore and Nikkei markets (Table 5, Panel A). For the study of volatility, (Table 5, Panel B), we observe a coefficient of 0.2711 which indicates that 7.3% of the variation in Hang Seng is explained by the variation in Nikkei. The other combinations produce larger values of 0.5558 and 0.3048; however, no combination produced a value greater than 31% of the variation in one index being associated with the variation in a second index. Due to large sample sizes, all the correlation coefficients calculated and observed resulted in p-values of less than 0.05. Although these values are statically significant, how important are they in predicting the covariation? The answer is simple: they would need to be much larger to predict the variation in one index when a second index changes. Some degree of association for mean and volatility in rates of return are associated with the same in a second market, nevertheless, we study other mitigating factors that may have large or additional influence.

Previous research on the relationship between large and small stock returns in six Asian (Pacific-Basin) nations and the association among

Panel-A: Rates of return			
	Hang Seng	**Nikkei**	**STI**
Hang Seng	1	0.4307	0.6639
Nikkei	0.4307	1	0.4657
STI	0.6639	0.4657	1
Panel-B: Volatility of return			
	Hang Seng	**Nikkei**	**STI**
Hang Seng	1	0.2716	0.5558
Nikkei	0.2716	1	0.3084
STI	0.5558	0.3084	1

Table 5: Pearson correlation coefficients (entire time period for each market).

the same six Asian financial markets is exemplified by Jarrett and Sun [2]. Their purpose was to provide evidence of the cross-autocorrelation of stock returns in a lengthy time period. Evidence was brought to bear as to the theoretical explanations for stock market behavior of Pacific-Basin nations including those with large financial markets, i.e., Japan and Hong Kong, and those with small financial markets, i.e., Thailand and Malaysia. This study, though different than ours, indicates clearly the relationship of large and small equity markets and gives us further desire to learn more about the co-integration of Asian equity markets.

We can now still learn more about the level of integration in our three markets by analyzing multiple regressions, and in doing so we exclude the influence of the delayed effects of lagged explanatory variables.

Regressions of the Rate of Return

We define the rate of return to be the percent change in the stock price from period t-1 to period t. According to the efficient markets hypothesis (EMH), the rate of return is difficult to predict with any reasonable level of accuracy. Hence, we wish to determine if there is validity in this hypothesis and whether rates of return in the three markets are correlated after excluding the influence of their own lagged values.

We construct a model to explain the Hang Seng rate of return by its own past values. By constructing a model with many lagged values of the rate of return and calculate the Akaike Information Criterion (AIC), we find that AIC is minimized at a lag of two. In turn, we find the first-order auto regression which appears in column (2) of Table 6. The coefficient (H1) is 0.0694 with a t-statistic of 3.2320 for all data which is significant at the reasonable level of $\alpha \le 0.05$. According to this result the weak form of the efficient markets hypothesis does hold for this time period. We repeat this process for the other two equity markets. For Nikkei, AIC is also minimized at a lag of two periods. The N2 coefficient is 0.0725 (t-statistic=2.8470). And for Singapore, AIC is minimized at lag of three periods. The STI3 coefficient is 0.0576 (t-statistic=3.0147). The results are mixed but all have t-statistics that are significant at $\alpha \le .01$. Next, we will further investigate this phenomenon by dividing the time series data into the same three sub-periods analyzed previously.

For all three equity markets, we subdivide the data into the three time periods noted previously. For the Hang Seng market, the lagged variable of two resulted in coefficients of 0.0659, 0.0779, and 0.0217 for the three time periods of pre-1997, 1997-2007, and post-2007, respectively. However, these two-period lagged coefficients were only statistically different from zero in the 1997-2007 time period. Thus, the results for the Hang Seng market are mixed. For the auto regression of the Nikkei market, we find the N2 coefficients to be 0.0812, 0.0194 and 0.0011 for the three time periods with none of them being statistically significant at a 95% confidence level. Recall that for the Nikkei, the entire period had a statistically significant coefficient of 0.0725. Hence, the individual sub-periods coefficients are of limited value and interpretation for the Nikkei. Lastly for Singapore (denoted STI), only the second period (1997-2007) has a coefficient that is statistically significant. The coefficient is 0.0979. The first and third periods were not statistically significant.

These results are not entirely the same as those of CL, JS, and JKK, but do indicate that change occurred among the three sample sub-periods. The results are mixed in all equity markets indicating different effects during the entire time period and differential effects in each of the sub periods. The data appear temporally affected although we cannot be certain about many interpretations of the results. Recalling, our purpose is to ascertain behavior backed up by the decision analytics of this and previous studies.

With the continued and dynamic development of the of the Asian equity markets, we should now observe the more recent analysis of their co-integration exhibited in Table 7. For all years in the Hang Seng, the results indicate that the current Hang Seng rate of return (the response variable) is associated with the current rates of return in the Tokyo and Singapore markets (explanatory variables). The coefficients are highly significant. There is no statistical significance between the current Hang Seng rate of return and the lagged rates of return of the markets in Tokyo (two period lag) and Singapore (three period lag). For all years in the Nikkei, the results are similar to the Hang Seng in that the other two markets (Hang Seng and Singapore) are significant (positive) predictors of the Hang Seng in the current period, but there is no significant relationship in the lagged values. Lastly, for the Singapore market, we again see a relationship in the current time period but no statistically significant relationships between markets in the lagged variables. Overall, the results in Table 7 support the notion that the three markets are integrated and have some association with each other during the entire time period studied. It should be noted that the strongest integration appears to be between the Hang Seng and Singapore markets as they have both the largest coefficients and largest t-statistics in each other's regressions.

By examining the three sub-periods (e.g., before 1997, 1997-

	Hang Seng (HS)				Nikkei (N)				STI			
	All Years	Pre-1997	1997-2007	Post-2007	All Years	Pre-1997	1997-2007	Post-2007	All Years	Pre-1997	1997-2007	Post-2007
cHS	0.0011	0.0024	0.0009	0.0000								
t	1.7301	1.9311	0.8495	-0.0073								
HS2	0.0694	0.0659	0.0779	0.0217								
t	3.2320	1.6160	2.3142	0.5819								
cN					-0.0004	-0.0011	-0.0007	0.0011				
t					-0.6319	-0.8985	-0.6399	0.9188				
N2					0.0725	0.0812	0.0194	0.0742				
T					2.8470	1.8390	0.4647	1.5278				
cSTI									0.0002	0.0009	0.0003	-0.0003
t									0.2946	1.0011	0.2908	-0.3996
STI3									0.0576	-0.0309	0.0979	0.0289
t									3.0147	-0.7954	3.1869	1.0496

Table 6: Auto regressions of the rates of return on equities listed in the three markets.

	Hang Seng (HS)				Nikkei (N)				STI			
	All Years	Pre-1997	1997-2007	Post-2007	All Years	Pre-1997	1997-2007	Post-2007	All Years	Pre-1997	1997-2007	Post-2007
C	0.0011	0.0024	0.0009	0.0000	-0.0004	-0.0011	-0.0007	0.0011	0.0002	0.0009	0.0003	-0.0003
t	1.7301	1.9311	0.8495	-0.0073	-0.6319	-0.8985	-0.6399	0.9188	0.2946	1.0011	0.2908	-0.3996
HS0					0.1955	0.0350	0.2227	0.3539	0.4868	0.3482	0.5458	0.5548
t					7.1260	0.7626	5.4784	5.5355	27.1408	11.9055	17.4568	18.1938
HS2	0.0694	0.0659	0.0779	0.0217	-0.0305	-0.0748	0.0018	-0.0383	-0.0194	0.0312	-0.0618	0.0064
t	3.2320	1.6160	2.3142	0.5819	-1.3417	-1.8567	0.0531	-0.7891	-1.0822	1.0611	-1.9836	0.2111
N0	0.1756	0.0358	0.2250	0.2083					0.2076	0.2082	0.1726	0.1843
t	7.1260	0.7626	5.4784	5.5355					10.2791	6.4230	4.5094	6.0447
N2	-0.0367	-0.0345	-0.0224	-0.0327	0.0725	0.0812	0.0194	0.0742	0.0044	0.0047	-0.0043	0.0151
t	-1.5166	-0.7705	-0.5343	-0.8760	2.8470	1.8390	0.4647	1.5278	0.2197	0.1451	-0.1100	0.4970
STI0	0.6990	0.6720	0.6390	0.8332	0.3319	0.3922	0.1999	0.4703				
t	27.1408	11.9055	17.4568	18.1938	10.2791	6.4230	4.5094	6.0447				
STI3	-0.0132	-0.0346	0.0037	-0.0103	-0.0406	0.0658	-0.0539	-0.0651	0.0576	-0.0309	0.0979	0.0289
t	-0.5736	-0.6404	0.1118	-0.3040	-1.6781	1.2327	-1.6201	-1.4805	3.0147	-0.7954	3.1869	1.0496
R-squared	0.4670	0.2752	0.4711	0.7078	0.2463	0.1298	0.2056	0.5083	0.4858	0.3311	0.4684	0.7130
SE of Reg	0.0244	0.0265	0.0259	0.0179	0.0258	0.0262	0.0258	0.0234	0.0204	0.0191	0.0239	0.0146

Table 7: Regressions of rate of return.

2007 and after 2007) one continues to observe small and some non-significant t-statistics among all the equity markets paired with each other. In general, statistical significance (or the lack thereof) between exchanges within the sub-periods between exchanges was consistent with significance in the entire period. Although the coefficients (and associated test statistics) tended to be larger in the latter two sub-periods than in the first sub-period. For example, for the Hang Seng regressions, the coefficients of N0 and STI0 were larger and the t-statistics larger in the 1997-2007 and post-2007 periods than in the pre-1997 period. For the Nikkei, one can see that the coefficients for HS0 and STI0 are largest in the post-2007 period. And finally for Singapore (STI), the HS0 coefficient is much larger in the two latter sub-periods, while the N0 variable coefficient and t-statistics are roughly the same throughout the three sub-periods.

Auto-regressions of the volatility of rates of return

We construct a regression model with the purpose of explaining the volatility in the Hang Seng and the other two equity markets. First, we account for the effects of their own volatility associated with their past values. Following CL and JS, the appropriate number of lagged explanatory variables to include in the respective models is determined by (1) the significance of individual parameter estimates; (2) by minimizing the AIC value; and (3) the presence or absence of serial correlation in the residual. By including one lagged response variable at a time, we follow CL, JS and JKK and observe the three criteria to construct a model explaining the current volatility in the three stock exchanges.

In Table 8, we find for Hang Seng that all lagged variables (four weeks' worth of lags) have significant t-statistics (2.9801, 4.0460, 4.6809 and 4.116). Tests for serial correlation applied to the model having four lagged values yield small and significant t-statistics. Nikkei (All Data) has large significant coefficients for lags 1, 2 and 3 but small and non-significant marginal coefficients for lag 4. For Singapore, significant lags were found at 1, 2, 3 and 4. There are some sub-periods for Nikkei and Hang Seng where non-significant coefficients occurred. In general, in the three markets, there tended to be significant autocorrelation up to lag 3. Similar results were found also when we observe the results of studying the individual three sub-periods noting that the sample sizes for sub periods are smaller than for the entire time period. Table 8 shows that significant auto-regressive coefficients in equity markets indicate an association with its own lagged variables. It is well-known that observations from previous studies including CL, JS and JKK resulted in a similar analysis and conclusions.

As before, we test for structural change in each equity market by dividing our time period into three sub periods. Although the results are universally similar, for the most part, the auto regressions for all three equity markets exhibit outcomes that are very similar to each other. Tests for equality among the three sub periods for each market would show the same results. In conclusion, all three markets suggest that each market has some parameter stability during the lengthy period studied and the effect of changes in time as expressed by the three sub periods indicate that this is true for each market but with some disparities.

At this point, we introduce lagged values of the other markets to ascertain whether the volatility in the former market indicates Granger causality [20]. To determine Granger causality in Hang Seng volatility, we choose the number of lagged values of the other indices volatility according to the criteria noted before (e.g., AIC and the absence of serial correlation in the residuals). Our results for the whole sample period (All Data), as reported in Table 9, indicate that we have only lag 1 for Nikkei and lag 1 for Singapore (zero lags are included for both.) The t-statistics for zero lags are significant for Nikkei and Singapore at a very small probability (significance level of $\alpha \leq 0.01$). Hence volatility in the Hang Seng equity market is associated with the lagged value in the other markets. Since the t-statistics are not significant for lagged values of 1 in Nikkei and Singapore, we cannot draw the same conclusion as in earlier studies. Thus, a Granger causality exists among the three Asian markets but we cannot extend the results to the lagged time periods. Hence, this indicates that the volatility in the markets for the entire time period were likely independent of each other. Some similarities exist in the Tables 9-11; however, we cannot be completely certain as to the exact relationship of the three markets. Future lengthier and wider studies of long-term data may indicate relationship that we have not discovered from this data.

Consistent with the findings of CL, we observed only the H1 (no lag) coefficients are at this time the coefficient is not significant (at α=0.05 or less). The AIC value suggests not including any lagged values of the Hang Seng variables. In addition, the Breusch-Godfrey test revealed the absence of serial correlation in the autoregressive model.

	Hang Seng				Nikkei				STI			
	All Years	**Pre-1997**	**1997-2007**	**Post-2007**	**All Years**	**Pre-1997**	**1997-2007**	**Post-2007**	**All Years**	**Pre-1997**	**1997-2007**	**Post-2007**
C	0.0250	0.0233	0.0264	0.0248	0.0224	0.0207	0.0227	0.0243	0.0194	0.0171	0.0223	0.0180
t	25.587	16.834	16.660	11.339	28.009	11.075	25.323	15.016	17.078	15.274	11.357	7.076
VLTY_HANG(-1)	0.0784	0.0042	0.1278	0.0705								
t	2.9801	0.0900	3.0755	1.3968								
VLTY_HANG(-2)	0.1059	0.1534	0.0478	0.1385								
t	4.0460	3.3211	1.1442	2.8135								
VLTY_HANG(-3)	0.1226	0.0821	0.0879	0.2315								
t	4.6809	1.7776	2.1045	4.7138								
VLTY_HANG(-4)	0.1080	0.0753	0.1275	0.0892								
t	4.1116	1.6336	3.0616	1.7683								
VLTY_NIKKEI(-1)					0.1522	0.1890	0.0399	0.2027				
t					5.7572	4.0148	0.9511	3.9971				
VLTY_NIKKEI(-2)					0.0744	0.0700	0.0770	0.0495				
t					2.7947	1.4726	1.8394	0.9597				
VLTY_NIKKEI(-3)					0.1021	0.1213	0.0776	0.0777				
t					3.8339	2.5500	1.8565	1.5053				
VLTY_NIKKEI(-4)					0.0451	0.1770	-0.0156	-0.0110				
t					1.7046	3.7578	-0.3713	-0.2172				
VLTY_STI(-1)									0.1502	0.0954	0.1533	0.1571
t									5.7472	2.0626	3.7486	3.0976
VLTY_STI(-2)									0.1201	0.1148	0.0578	0.2704
t									4.5843	2.4759	1.4033	5.4253
VLTY_STI(-3)									0.1324	0.0774	0.0921	0.2420
t									5.0536	1.6706	2.2371	4.8562
VLTY_STI(-4)									0.1519	0.0941	0.2185	-0.0182
t									5.8340	2.0785	5.3483	-0.3587

Table 8: Auto regressions of volatility of equity prices.

	All Years	Pre-1997	1997-2007	Post-2007
constant	0.0072	0.0096	0.0078	0.0062
t	6.2756	3.9706	3.7038	3.8247
H0				
t				
H1	0.0181	-0.0171	0.0575	0.0293
t	0.6832	-0.3684	1.3687	0.5719
H2	0.0622	0.1465	0.0258	0.0014
t	2.7874	3.2980	0.7399	0.0399
H3	0.0570	0.0744	0.0470	0.0463
t	2.5461	1.6759	1.3446	1.2818
H4	0.0413	0.0552	0.0386	0.0313
t	1.8323	1.2415	1.1003	0.8674
N0	0.1144	0.0119	0.0903	0.1851
t	4.3082	0.2371	1.9260	4.7361
N1	-0.0021	0.0146	-0.0074	0.0265
t	-0.0794	0.2897	-0.1533	0.6597
STI0	0.5356	0.4056	0.5290	0.6705
t	20.9238	6.7833	14.7450	14.4441
STI1	0.0148	0.0060	0.0229	-0.0722
t	0.5044	0.0942	0.5436	-1.2448

Table 9: Regressions of volatility of equity returns.

	All Years	Pre-1997	1997-2007	Post-2007
constant	0.0096	0.0078	0.0158	0.0081
t	8.4516	3.8930	8.0776	3.8863
N0				
t				
N1	0.1240	0.1711	0.0129	0.1364
t	4.6691	3.7345	0.3004	2.6559
N2	0.0447	0.0724	0.0521	-0.0166
t	1.7485	1.5780	1.2389	-0.3806
N3	0.0861	0.1113	0.0810	0.0363
t	3.3705	2.4201	1.9249	0.8347
N4	0.0256	0.1769	-0.0321	-0.0448
t	1.0128	3.8759	-0.7625	-1.0586
H0	0.1146	0.0086	0.0687	0.2975
t	4.4347	0.2077	1.8344	4.7029
H1	-0.0109	0.0234	-0.0307	-0.0231
t	-0.4201	0.5659	-0.8204	-0.3538
STI0	0.1937	0.1440	0.1150	0.3517
t	6.8208	2.5456	3.0892	4.9835
STI1	0.0034	-0.0849	0.0325	0.0174
t	0.1180	-1.4639	0.8603	0.2361

Table 10: Regressions of volatility of equity returns.

The model with one Shanghai lagged variable (S1) is not considered in this study. The negative coefficients corroborates the results of CL but in this study this coefficient is not estimated.

An additional question relates to whether or not there is significant co-variation of volatility in a multivariate setting. To incorporate instantaneous causality in explaining Hang Seng volatility, one adds the current value of the variable in the other markets into the auto-regression. The coefficients for the Nikkei (All Years) show some positive coefficients but only N0 is significant. This would indicate that extended time period in this study resulted in Hang Seng volatility not significantly related to Nikkei volatility in a lagged time period. Within sub-periods, we observe that the pre-1997 period has a t-statistic for N0 that is not significant, while the other two time periods are significant. Like the Nikkei, lagged one period Singapore volatility is not a significant predictor of the Hang Seng volatility. However, Singapore volatility is more strongly related to the Hang Seng volatility in the

	All Years	Pre-1997	1997-2007	Post-2007
constant	-0.001	0.005	-0.002	-0.002
t	-0.617	2.675	-0.886	-1.865
STI0				
t				
STI1	0.098	0.077	0.077	0.167
t	3.695	1.616	1.844	3.277
STI2	0.082	0.123	0.026	0.160
t	3.652	2.730	0.762	4.415
STI3	0.079	0.046	0.073	0.086
t	3.482	1.022	2.084	2.356
STI4	0.086	0.045	0.120	-0.018
t	3.814	0.987	3.381	-0.504
H0	0.426	0.2133	0.508	0.521
t	20.639	6.576	14.324	14.527
H1	-0.016	0.020	-0.019	-0.060
t	-0.681	0.578	-0.450	-1.339
N0	0.151	0.100	0.138	0.155
t	6.371	2.722	2.973	4.529
N1	-0.009	0.015	0.058	-0.079
T	-0.370	0.396	1.223	-2.260

Table 11: Regressions of volatility of equity returns.

current period. It is significant within all the sub-periods, including the pre-1997 time period unlike the Nikkei.

If we go line by line and column by column through all the data in Tables 10 and 11, we find consistency from period to period in pairwise combinations of one variable and its relationship with lagged 1 of the another market's variable. Market volatility does not have a lasting effect. In a lag of only one period, we do not see evidence of a lasting effect on the volatility of a second equity market in markets of Asia. Of course, our conclusions are limited to the three markets studied and the time period under investigation extending the time periods to include more distant data in the past would probably no change the overall conclusion since our time period is long at this point. Observing Table 10, N1, N3 and N4 and STI0, as well as the constant term, have coefficients with significant t-statistics (p-value less than 0.05). This indicates that Nikkei has serial correlation at lags of 1, 3 and 4 and contains one additional coefficient with Singapore at zero lag. In period 2, only STI0 and N3 (along with the constant term) are significant. And in period 3, coefficients are significant for N1, H0 and STI0 (and the constant term). Hence there is no evidence of consistency in the three sub-periods.

Our analysis indicates that the three sub-periods are not identical to each other and the data analytical results correspond to the notion that this is reasonable. Financial economic events in Asia indicate as noted in this study do show that external effects from other parts of the World do influence the markets studied. However, our purpose was not to measure overseas effects but Asia is not an isolated area of the Earth.

We observe the same lack of consistency in the finding for Singapore (Table 11.) Lags for STI1, STI2, STI3, and STI4, as well as H0 and N0 contain, significant t-statistics when the entire period's volatility for Singapore is analyzed. However, within individual sub-periods, these significances disappear in some cases. For example, STI1, STI3, and STI4 are not significant in the pre-1997 (1987-1997 in this study) period, while STI2 is not significant for the 1997-2007 period, and STI4 is not significant for the post-2007 period.

Without going through the analysis to compare individual coefficients, we observe the diversity of differences from the change in time and pairwise relationships in markets. As long as economic conditions change, the results include temporal instabilities in markets. Our study is lengthy and exhaustive but much of its results are not unnerving since we already know that markets vary in price and volatility, but these factors have components that are predictable using modern time series analysis. See Ray, Chen and Jarrett where the authors show that firms listed on the Tokyo exchange contain components (permanent and temporary) which may in turn lead to better predictions.

Overall, when analyzing the results for the models of the volatility in equity returns for all three markets, we find the effect of the Asian equities leading to the same form of temporal instability of the parameters as seen among the Western equity markets. Simply stated the inclusion of the Hang Seng or Tokyo variables do not result in stable relationships throughout the three sub periods studied. There are observed structural changes related to each time period. Hence, we conclude that the concept of temporal stability is not present.

Conclusions

We collected, analyzed and interpreted an extensive database of the stock market indices for equity markets of Tokyo, Singapore and Hong Kong (Hang Seng). Our purpose is to draw conclusions concerning the relationships of the various equity markets expressed by an analysis of the mean and volatility of rates of return in the three stock exchanges over a lengthy period of time and during three distinct sub-periods. We initially examined the time series characteristics of stock price indices for all three exchanges during the period of 1987 to 2015. Specifically, we calculated the rate of return and the volatility of returns for the three markets and estimated the serial correlation and co-movement of the equity markets. Volatility in the rates of return also differs among the three equity exchanges. Across the three sub-periods defined by time the relationship are not stable. This, perhaps, is the most crucial of the general findings of this analysis. Relationships among the markets across time periods change. Investigations into the influences of the economic environment in which the markets operate indicate some of the causes are changes in variability and volatility of the rates of return (or at least associations with these changes). This adds to ones knowledge of explaining and predicting relationships among the three exchanges. The evidence presented in this study is largely consistent with other studies of the relationship among equity markets in three or more nations.

Furthermore, we find that serial correlation also differs in the three equity markets. The use of multivariate time series analysis [21-26] may provide further evidence for the lack of co-integration in these stock exchanges. One last suggestion is to examine each individual index to access where there are temporary and permanent components in these indices in the manner of Ray, Chen and Jarrett [19] for the Japanese market. This would answer questions concerning temporal stability in the indices of Asian equity markets. In the future, we expect time series studies to continue in areas of the so-called emerging markets of Asia (and South America as well) to relate in a similar context the extent to which emerging markets, i.e., India, China and others, are related to influences by the developed nations of Europe, North America and Japan.

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