Elsevier Editorial(tm) for Economics Letters
Manuscript Draft

Manuscript Number:

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Article Type: SCO Original Article

Keywords: Non-linearity; Bicorrelation; Windowed testing; Episodic behavior; Asian stock markets.

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* Manuscript

Full Title: **CROSS-TEMPORAL UNIVERSALITY OF NON-LINEAR SERIAL DEPENDENCIES: EVIDENCE FROM ASIAN STOCK INDICES**

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Abstract: This study utilizes the Hinich portmanteau bicorrelation test in conjunction with the windowed testing procedure to examine the cross-temporal universality of non-linear serial dependencies in the returns for Asian stock market indices. As a whole, the results reveal that the non-linear serial dependencies do not appear to be persistent across time for all the markets.

JEL Classification: G15; C49.

Keywords: Non-linearity; Bicorrelation; Windowed testing; Episodic behavior; Asian stock markets.

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1. Introduction

Testing for non-linearity in stock returns series has become extremely popular in the financial econometrics literature in recent years. Antoniou *et al*. (1997) and Sarantis (2001) listed several possible factors that might induce non-linearity in stock returns. Among them are difficulties in executing arbitrage transactions, market imperfections, irrational investors' behavior, diversity in agents' beliefs, and heterogeneity in investors' objectives. In the literature, much of the earlier evidence of non-linearity was drawn from stock markets of developed countries such as the U.S. (Hinich and Patterson, 1985; Scheinkman and LeBaron, 1989; Hsieh, 1991) and U.K. (Abhyankar *et al*., 1995; Opong *et al*., 1999). However, in recent years, more and more evidence of non-linearity from emerging stock markets are documented[1] and this strongly suggests that non-linearity is a cross-sectionally universal phenomenon.

Since the existence of non-linearity implies the potential of financial returns predictability, the empirical evidence has contributed to the phenomenal growth of non-linear models in the literature. However, the evidence to date on the out-of-sample forecasting performance of non-linear time series models is largely negative (see, for example, Diebold and Nason, 1990; Ramsey, 1996; Brooks and Hinich, 2001). Hinich and Patterson (1995) conjectured that this failure is caused by the episodic transient nature of the non-linear dependencies. In other words, a relatively few brief periods of strong non-linearity are actually driving the results of the overall sample and trigger the rejection of the null of linearity. One approach to support the

[1] For instance, Antoniou *et al* (1997)- Turkey; Panas (2001)- Greece; Ammermann and Patterson (2003)- included Hong Kong, Singapore and Taiwan; Joe and Menyah (2003)- eleven African markets; Lim and Liew (2004)- five Southeast Asian markets.

above conjecture is to break the full sample into smaller sub-samples, and determine whether the non-linear dependencies appear to be cross-temporally universal. However, this approach requires non-linearity test that has good sample properties over short horizons of data. The Hinich portmanteau bicorrelation test (Hinich and Patterson, 1995; Hinich, 1996) in conjunction with a procedure of dividing the full sample period into shorter windows of time (known as the windowed testing procedure) are designed for this particular purpose (for application in financial markets, see for example, Hinich and Patterson, 1995; Brooks and Hinich, 1998; Brooks *et al*., 2000; Ammermann and Patterson, 2003; Lim *et al*., 2003). To the best of our knowledge, though abundant evidence of non-linearity is reported for Asian stock markets, the cross-temporal universality of these detected non-linear serial dependencies has hardly received a mention in the literature, with the exception of Taiwan Stock Exchange by Ammermann and Patterson (2003). Thus, this study attempts to fill this void in the empirical literature.

2. Methodology

This section provides a brief description of the windowed testing procedure and the bicorrelation test statistic (denoted as H statistic). Let the sequence $\{y(t)\}$ denote the sampled data process, where the time unit, t, is an integer. The test procedure employs non-overlapped data window, thus if n is the window length, then k-th window is $\{y(t_k), y(t_k+1),\ldots, y(t_k+n-1)\}$. The next non-overlapped window is $\{y(t_{k+1}), y(t_{k+1}+1),\ldots y(t_{k+1}+n-1)\}$, where $t_{k+1} = t_k+n$. The null hypothesis for each window is that $y\{t\}$ are realizations of a stationary pure noise process that has zero bicovariance. The alternative hypothesis is that the process in the window is random with some nonzero bicorrelations $C_{yyy}(r, s) = E[y(t)y(t+r)y(t+s)]$ in the set $0 < r < s < L$, where L is the number of lags.

We state without proof and derivation that the H statistic[2] is defined as:

$$H = \sum_{s=2}^{L}\sum_{r=1}^{s-1} G^2(r,s) \quad \sim \; \chi^2_{\,(L\text{-}1)\,(L/2)} \tag{1}$$

where $G(r,s) = (n-s)^{\frac{1}{2}} C_{ZZZ}(r,s)$, and $C_{ZZZ}(r,s) = (n-s)^{-1}\sum_{t=1}^{n-s} Z(t)Z(t+r)Z(t+s)$

for $0 \leq r \leq s$. $Z(t)$ are the standardized observations, obtained by subtracting the sample mean of the window and dividing by its standard deviation. The number of lags L is specified as $L= n^b$ with $0 < b < 0.5$, where b is a parameter under the choice of the user. Based on the results of Monte Carlo simulations, Hinich and Patterson (1995) recommended the use of b=0.4 in order to maximize the power of the test while ensuring a valid approximation to the asymptotic theory. In this test procedure, a window is significant if the H statistic rejects the null of pure noise at the specified threshold level.

3. The Data

The data consist of daily closing prices for selected Asian stock market indices: Bangkok S.E.T. (Thailand), Colombo SE All Share (Sri Lanka), Hang-Seng (Hong Kong), India BSE National (India), Jakarta SE Composite (Indonesia), Karachi SE 100 (Pakistan), Korea SE Composite (South Korea), Kuala Lumpur Composite

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[2] Interested readers can refer Hinich and Patterson (1995) and Hinich (1996) for a full theoretical derivation of the *H* statistic and some Monte Carlo evidence on the good small sample properties of the test.

(Malaysia), Nikkei 225 Stock Average (Japan), Philippines SE Composite (the Philippines), Shanghai SE Composite (China), Singapore Straits Times (Singapore) and Taiwan SE Weighted (Taiwan). All these indices collected from *Datastream* are denominated in their respective local currency units for the sample period 1/1/1990 to 31/12/2003, with the exception of Shanghai SE Composite[3]. The data are transformed into a series of continuously compounded percentage returns, r_t = 100* ln(p_t/p_{t-1}), where p_t is the closing price of the index on day t, and p_{t-1} the price on the previous trading day. To apply the bicorrelation test in conjunction with the windowed testing procedure, all the returns series are split into a set of non-overlapping windows of 35 observations in length. According to Brooks and Hinich (1998), the window length should be sufficiently long to provide adequate statistical power and yet short enough for the test to be able to pinpoint the arrival and disappearance of transient dependencies. In fact, it was found that the choice of the window length does not alter much the results of the significant H statistics in this study

4. Empirical Results

Before proceeding with the bicorrelation test, we first remove linear dependencies from the returns series by fitting an autoregressive model. The bicorrelation test is then applied to the residuals of the fitted AR(p) model, so that a rejection of the null of pure noise at the specified threshold level is due to significant non-linearity. Table 1 presents the results of the bicorrelation test using the windowed testing procedure for all the Asian stock returns series. The fourth row shows the number of windows where the null of pure noise is rejected by the H statistic (with percentage in

[3] Since the Shanghai Stock Exchange was established in December 1990, the sample period spans from 2/1/1991 to 31/12/2003.

parenthesis)[4]. For instance, for the BSENAT returns series, the null is rejected in 5 windows by the *H* statistic, which is equivalent to 4.81%. As a whole, the results reveal that the non-linear serial dependencies do not appear to be persistent across time for all markets. Instead, all the Asian stock returns series seem to be characterized by relatively few brief episodes of highly significant non-linearity surrounded by long periods of pure noise. In fact, it is possible that the evidence of non-linearity in Asian stock indices reported by Ammermann and Patterson (2003) and Lim and Liew (2004) is actually driven by a number of sub-periods in which the *H* statistics are significant. This is not surprising given the high power of the portmanteau non-linearity tests employed in these two studies. The last row of Table 1 provides the dates when these dependencies occurred, which is potentially useful for future investigation into the events that lead to this non-linear behavior in each of the Asian stock markets (see, for example, Brooks *et al.*, 2000).

<<Insert Table 1 about here>>

5. Conclusion

This study utilizes the Hinich portmanteau bicorrelation test in conjunction with the windowed testing procedure to examine the cross-temporal universality of non-linear serial dependencies in the returns for Asian stock market indices. The results reveal

[4] In this study, the threshold level was set at 0.01. The level of significance is the bootstrapped thresholds that correspond to 0.01. The *H* statistics are computed using the T23 program, which is available upon request from the authors.

that the non-linear serial dependencies do not appear to be persistent or stable across time for all markets. Instead, all the Asian stock returns series seem to be characterized by relatively few brief periods of highly significant non-linearity, surrounded by long time periods in which the returns follow pure noise process. The modeling of the detected non-linearity seems to be difficult due to its episodic transient occurrences and this provides a plausible explanation to the existing negative evidence on out-of-sample forecasting performance of non-linear time series models. It would be fruitful for future studies to determine whether such phenomenon prevails in individual stocks traded on these Asian stock markets.

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Table 1
Windowed Testing Results for Asian Stock Returns Series

	BSENAT	BSET	CSEALL	HKHS	JSE	KLCI	KOSPI	KSE100	NIKKEI	PSE	SSE	SST	TAIEX
Fitted AR(*p*) model	AR(2)	-	AR(2)	AR(1)	AR(1)	AR(3)	AR(1)	AR(2)	-	-	AR(1)	AR(2)	AR(2)
Total number of windows	104	104	104	104	104	104	104	104	104	104	96	104	104
Significant *H* windows	5 (4.81%)	6 (5.77%)	7 (6.73%)	4 (3.85%)	2 (1.92%)	4 (3.85%)	1 (0.96%)	7 (6.73%)	3 (2.88%)	3 (2.88%)	5 (5.21%)	6 (5.77%)	5 (4.81%)
Dates of significant *H* windows	17/8/93 4/10/93	29/1/91 18/3/91	19/4/94 6/6/94	7/5/91 24/6/91	23/10/90 10/12/90	13/8/91 30/9/91	11/12/90 28/1/91	29/5/90 16/7/90	7/5/91 24/6/91	20/2/90 9/4/90	1/10/92 18/11/92	20/2/90 9/4/90	1/1/90 19/2/90
	7/6/94 25/7/94	13/8/91 30/9/91	7/6/94 25/7/94	26/8/97 13/10/97	23/4/96 10/6/96	7/2/95 27/3/95		26/7/94 12/9/94	7/6/94 25/7/94	17/7/90 3/9/90	24/11/94 11/1/95	13/8/91 30/9/91	13/9/94 31/10/94
	28/3/95 15/5/95	10/10/95 27/11/95	28/11/95 15/1/96	14/10/97 1/12/97		4/8/98 21/9/98		20/12/94 6/2/95	11/6/96 29/7/96	14/10/97 1/12/97	28/3/96 15/5/96	14/4/92 1/6/92	16/5/95 3/7/95
	14/10/97 1/12/97	20/1/98 9/3/98	10/11/98 28/12/98	2/12/97 19/1/98		4/9/01 22/10/01		5/3/96 22/4/96			31/7/97 17/9/97	11/1/94 28/2/94	5/3/96 22/4/96
	19/11/02 6/1/03	7/12/99 24/1/00	19/10/99 6/12/99					22/9/98 9/11/98			9/7/98 26/8/98	4/7/95 21/8/95	4/8/98 21/9/98
		4/9/01 22/10/01	4/9/01 22/10/01					7/5/02 24/6/02				14/10/97 1/12/97	
			25/6/02 12/8/02					3/6/03 21/7/03					

Note: BSENAT- India BSE National; BSET- Bangkok S.E.T; CSEALL- Colombo SE All Share; HKHS- Hang Seng; JSE- Jakarta SE Composite; KLCI- Kuala Lumpur Composite; KOSPI- Korea SE Composite; KSE100- Karachi SE 100; NIKKEI- Nikkei 225 Stock Average; PSE- Philippines SE Composite; SSE- Shanghai SE Composite; SST- Singapore Straits Times; TAIEX- Taiwan SE Weighted.