E C O N O M I C S   B U L L E T I N

Cross−temporal universality of non−linear dependencies in Asian stock markets

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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 dependencies in the returns series for Asian stock market indices. As a whole, the detected non−linear dependencies do not appear to be persistent or stable across time for all the stock markets. In particular, the underlying process is of a switching type, with the pure noise process from time to time switches to a non−linear dependent stochastic process for some unknown length of time, and then switches back to pure−noise. This provides a plausible explanation for the disappointing forecasting performance of many non−linear models, as these existing models do not take note of the episodic transient nature of the non−linear dependency structures.

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1. Introduction

It is an accepted fact that financial economics has been dominated over the past few decades by linear paradigm, with linear models been widely employed in the time series analysis of financial data. However, the adequacy of conventional linear models has been challenged in recent years, as abundant evidence has emerged in the literature to suggest non-linearity is a universal phenomenon, at least for time series data of stock prices. This growing body of research covers stock markets of the U.S. (Hinich and Patterson, 1985; Scheinkman and LeBaron, 1989; Hsieh, 1991), U.K. (Abhyankar *et al*., 1995; Opong *et al*., 1999), Germany (Kosfeld and Robé, 2001), G-7 countries (Sarantis, 2001), Turkey (Antoniou *et al*., 1997), Greece (Barkoulas and Travlos, 1998; Panas, 2001), eleven African markets (Joe and Menyah, 2003), five Southeast Asian markets (Lim and Liew, 2004), and random sample of world stock markets (De Gooijer, 1989; Ammermann and Patterson, 2003). The above stylized fact of stock returns is hardly surprisingly as Antoniou *et al*. (1997) and Sarantis (2001) listed several possible factors that might induce significant non-linearities in stock market. Among them are difficulties in executing arbitrage transactions, market imperfections, irrational investors' behavior, diversity in agents' beliefs, and heterogeneity in investors' objectives.

As mentioned earlier, the existence of non-linearity calls into question the adequacy of linear models, and hence invites the development of non-linear time series models which are expected to provide superior forecasts than their linear counterparts or the naïve random walk. However, the evidence to date on the out-of-sample forecasting performance of non-linear time series models is still unconvincing (see, for example, Diebold and Nason, 1990; Ramsey, 1996; Brooks, 1997; Brooks and Hinich, 2001). Hinich and Patterson (1995) conjectured that the inability of researchers to make meaningful point forecasts of stock returns despite strong evidence of non-linear dependence is caused by the episodic transient nature of the dependencies. In particular, the high power of extant non-linearity tests masks the episodic appearance and disappearance of non-linear dependence in stock returns. Ramsey (1996) explained in details the disappointing forecasting performance of non-linear models. Among others, economic systems are typically open and non-isolated which cannot be forecasted, and successful forecasting requires global constraints to be met. Brooks and Hinich (2001) argued that the poor performance is due to the portmanteau or general nature of existing non-linearity tests which do not have specific alternative hypotheses. In this regard, the only information obtained from the rejection of the null hypothesis is linear or non-linear, and does not provide a direct guide to the specification of an appropriate non-linear time series model (for similar argument, refer Brooks, 1998; Rothman, 1999). Thus, it is possible the specification of the non-linear time series equations used for forecasting are not models of the type that caused the rejections of the linear or i.i.d. null in these non-linearity tests. The above explanations should not be viewed as competing but rather complementary in the sense that they provide useful guides for researchers in their continuous effort to improve forecasts of the detected non-linear systems.

The present study attempts to draw further empirical support from Asian stock markets to the conjecture of Hinich and Patterson (1995). The episodic transient behavior of non-linear dependencies has been noted in many other recent studies using the windowed testing approach (see, for example, Brooks and Hinich, 1998; Brooks *et al*., 2000; Ammermann and Patterson, 2003; Lim *et al*., 2003). With different methodology of waveform dictionaries, Ramsey and Zhang (1997) found similar structures, in which the price activities are characterized by intermittent bursts of activity involving narrow range of frequencies, surrounded by longer periods of quiescent periods. One approach to support the conjecture of Hinich and Patterson (1995) is to break the full sample into smaller sub-samples (known as windows), and determine whether the non-linear dependencies appear to be cross-temporally universal, that is whether they are stable and of constant strength across time[1]. 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. To the best of our knowledge, though abundant evidence of non-linearity has been reported for Asian stock markets, the cross-temporal universality of the detected non-linear 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 non-zero 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:

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

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.

[1] It is important to note that the stability of the parameter estimates over the whole data series when estimated in epochs is one of the global criteria highlighted in Ramsey (1996).
[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.

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 (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 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).

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

[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.

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.

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 series for Asian stock market indices. The results reveal 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 appears to be problematic as the underlying process is of a switching type, with the pure noise process from time to time switches to a non-linear dependent stochastic process for some unknown length of time, and then switches back to pure-noise. This provides a plausible explanation for the disappointing forecasting performance of many non-linear models, as these existing models do not take note of the episodic transient nature of the non-linear dependency structures. Though building an appropriate non-linear model of the switching type is a daunting task, the present results are in no way an indictment of the usefulness of non-linear time series models for yielding superior forecasts. Instead, the continuous efforts to improve on the extant non-linear models would be well rewarded, with particular attention given to the substantial instability in the non-linear dependencies.

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