Nonlinear Behavior of the Chilean Capital Markets

Claudio A. Bonilla Rafael Romero-Meza Elizabeth Gutiérrez

Abstract

This article checks for the efficiency of the Chilean stock market. To conduct our analysis we use the Hinich bicorrelation test with a windowed test procedure to detect non-linear behavior in the rates of return of twelve major Chilean companies whose stock is traded on the Santiago Stock Exchange and included in the Selective Stock Price Index (IPSA). Our results reveal the existence of significant periods of non-linearity, suggesting that stock returns do not follow a random path and thus leading us to reject the weak form of the efficient market hypothesis. However, the non-linear serial dependencies were found to be episodic, the returns series displaying statistically significant non-linear periods that were few and short-lived followed by long periods of returns exhibiting a white noise process. These findings using the Hinich test were support by the alternative indicators.

EL Classification: C12, G14

Key words: Nonlinear time series, Chilean stock market, episodic nonlinearity, Hinich portmanteau bicorrelation test.

Introduction

Market efficiency has always been a topic of great interest in the financial and capital markets literature. Numerous empirical studies since the seminal works of Samuelson (1965) and Fama (1970) have attempted to prove that financial markets behave in accordance with the efficient market hypothesis (EMH).

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This theory holds that stock market prices obey a random walk model and are therefore independent and identically distributed. Any potential for predictability is thus ruled out, and so, consequently, is any opportunity for abnormal investor gains.

Research into market efficiency has traditionally focused strictly on the linear predictability of financial time series. However, since Hinich and Patterson published their ground-breaking work (1985) providing evidence for non-linear behavior among a large proportion of the stocks traded on the NYSE, studies of such non-linearity have become a growing area of specialization within financial econometrics (see Tsay, 1986; Brock, Dechert and Scheinkman, 1987; White, 1989 and 1990). Saadi and Gandhi (2006) argue that studies of the random walk hypothesis must be designed to detect both linear and non-linear dependencies, as share price movements that appear unpredictable under linear models may be predictable if non-linear ones are employed. Not including non-linear models may thus lead to erroneous acceptance of EMH, a case of a Type II error.

Although there now exists an extensive literature on capital market efficiency and stock returns, most of these works concentrate on the developed countries. But with the increasing number of emerging markets among the less-developed nations and their ever-larger role in international portfolio diversification, the study of these markets is becoming ever more necessary. With a view to helping palliate the lack of such research, this paper offers an analysis of the Chilean stock market, considered to be one of the most significant in Latin America.

After growing vigorously between 1980 and 1995, the Chilean stock market showed meager returns on its main indices from 1996 until 2003. Since 2004, however, shares have recovered to the point where they are currently the principal source of profitability in Chile's financial system.

To conduct our analysis we use the Hinich bicorrelation test with a windowed test procedure to detect non-linear behavior in the rates of return of twelve major Chilean companies whose stock is traded on the Santiago Stock Exchange and included in the Selective Stock Price Index (IPSA), the principal share index published by the Exchange. To reinforce our conclusions we also subject them to Engle's LM test and the BDS test, two alternative indicators that use a different statistical approach to check for non-linear behavior in the entire sample.

Our results reveal the existence of significant periods of non-linearity, suggesting that stock returns do not follow a random path and thus leading us to reject EMH. However, the non-linear serial dependencies were found to be episodic, the returns series displaying statistically significant non-linear periods that were few and short-lived followed by long periods of returns exhibiting a white noise process. These findings using the Hinich test were support by the alternative indicators.

The remainder of this paper is organized as follows: Section II contains a review of the literature, Section III provides a description of the data, Section IV outlines the methodology employed, Section V summarizes the results of the study, Section VI sets out the findings of the alternative non-linear BDS and Engle's LM tests, and finally, Section VII presents our conclusions.

I. Related literature

The first academic efforts at modeling non-linear economic dynamics were undertaken by Kaldor (1940), Hicks (1950) and Goodwin (1951) in the form of investigations into the business cycle. Years later, Takens (1981) and Grassberger and Procaccia (1983) published their studies on chaotic processes caused by non-linear dependencies in data series. But it was not until the work of Hinich and Patterson (1985), Brock (1986) and Hsieh (1989) that the statistical tools needed to identify the presence of non-linearity in financial data series became available (Brooks, 1996).

Since then, evidence for episodes of non-linear behavior in financial asset markets has continued to mount. Studies have reported non-linearity in the American market, as demonstrated by Hinich and Patterson (1985), Scheinkman and LeBaron (1989), Hsieh (1991), Brock et al. (1992), Hsieh (1995), Kohers et al. (1997), Patterson and Ashley (2000) and Skaradzinski (2003); in European markets, as shown in Panunzi and Ricci (1993), Abhyankar et al. (1995), Brooks (1996), Brooks et al. (1998), Afonso and Teixeira (1998), Opong et al. (1999), Brooks and Hinich (2001), Kosfeld and Robé (2001), Fernández et al. (2002) and Panagiotidis (2005); in Asian markets, as discovered by Antoniou et al. (1997), Ammermann (1999), Ahmed et al. (1999), Ammermann and Patterson (2003), Lim et al. (2003) and Lim and Hinich (2005); and finally, in Latin American markets, as revealed by the findings of Bonilla et al. (2006) and Romero-Meza et al. (2006).

Among the above-cited works, various applications may be found that use the Hinich bicorrelation test in combination with a windowed test procedure (Hinich 1996) for detecting non-linear dependencies in stock return series. Specific examples are Brooks and Hinich (1998), Ammermann (1999), Ammermann and Patterson (2003), Skaradzinski (2003), Lim et al. (2003), Lim and Hinich (2005) and Bonilla et al. (2006).

Brooks and Hinich (1998) tested the validity of specifying a GARCH error structure for financial time-series data on the pound sterling exchange rate for a set of ten currencies. Their results demonstrated that there is a structure statistically present in the data that cannot be captured by a GARCH model or any of its variants. Ammermann (1999), studying the Taiwan Stock Exchange and share indices of other exchanges such as New York, London, Tokyo, Hong Kong and Singapore, found support for non-linear behavior in the data series. Ammermann and Patterson (2003) analyzed various international financial indices to determine the degree of dispersion of the non-linearity, and then analyzed the Taiwan stock market to determine whether the phenomenon is truly characteristic of financial time series. Their results indicate that non-linearity among them is in fact universal, to be found in all markets studied and the vast majority of investigated stocks traded on the Taiwanese exchange. Skaradzinski (2003) analyzed 60 stocks on the NYSE representing companies with varying market capitalizations for odd years between 1993 and 2001, and the results obtained evince a significant statistical difference in the level and incidence of non-linear behavior among portfolios of different capitalization categories. Highly capitalized stocks show the greatest levels and incidences of non-linearity, followed by medium and thinly capitalized ones. These differences were more pronounced at the start of the nineties, but remain significant for the entire period. Non-linear correlation grew over the course of the decade under study for all portfolios, while linear correlation declined. There were also cases of sporadic correlation among the portfolios, suggesting that the relationship is more dynamic than was previously thought.

As for Lim et al. (2003), their study tested the adequacy of the GARCH model for describing the generating process behind the Malaysian stock market. The bicorrelation results they obtained confirmed that the model does not deliver an adequate characterization of the process in this market. Lim and Hinich (2005) analyzed the existence of non-linearity in Asian financial markets, studying 14 different stock indices. They found that non-linear dependency does not seem to persist over time but nevertheless is sufficiently significant to balance out the long periods of tranquility, and thus were led to reject the hypothesis of white noise in the series. For what concerns Latin America, exceptions to the general dearth of market non-linearity studies are Bonilla et al. (2006) and Romero-Meza et al. (2006). The first of these verified that non-linear periods for stock returns in the main Latin American indices are episodic, while the second one detected the principal political and economic events that explained such episodes in the Chilean stock market at the aggregate index level (IPSA).

II. The data

As noted earlier, the data for this study consist of the daily returns for twelve companies included in IPSA, the principal share index compiled by the Chile Stock Exchange. The firms were chosen for their relative importance in the index; the data themselves were obtained from Economática.

Stock returns are derived from closing prices according to the following expression: $r_t = \ln(\frac{p_t}{p_{t-1}})$, where r_t is the return on the share in period t, p_t is the closing price in period t and p_{t-1} is the closing price in period $t-1$.

Table 1 shows the number of data items and corresponding period for each company in our analysis.

<Insertar Tabla 1>

Table 2 summarizes the principal statistical characteristics for the share return series.

<Insertar Tabla 2>

With the exception of BCI, CHILECTRA and ENTEL the series all display a positive skewness coefficient,[1] indicating that the right tail of the distribution is larger. As regards the shape of the tails, the indices of all of the companies exhibit kurtosis greater than 3,

[1] $S = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{X_t - \bar{X}}{\hat{\sigma}}\right)^3$. For a normal distribution, the coefficient is zero.

meaning their distributions are leptokurtic, or more peaked than the normal distribution.[2] The companies' daily returns are therefore not normally distributed, a conclusion confirmed by the Jarque-Bera (JB) test[3] which rejects the null hypothesis for all of the firms at the 99% significance level.

III. Methodology

In this section we briefly review the windowed test procedure and the bicorrelation test developed by Hinich (1996).[4] Let sequence $\{x(t)\}$ be the sample data process in which the time unit t is an integer. The test procedure uses non-overlapping windows such that if n denotes window length, then the kth window is $\{x(t_k), x(t_k + 1), \ldots\ldots. x(t_k + n - 1)\}$. The next non-overlapping window, k+1, is thus $\{x(t_{k+1}), x(t_{k+1} + 1), \ldots\ldots. x(t_{k+1} + n - 1)\}$, where $t_{k+1} = t_k + n$. The null hypothesis for each window is that the $x(t)$ are occurrences of a pure noise stationary process whose bicovariance is 0. The alternative hypothesis is that the process is random with some non-zero correlations $C_{xxx}(r) = E[x(t)x(t+r)]$ or non-zero bicorrelations $C_{xxx}(r,s) = E[x(t)x(t+r)x(t+s)]$ on the set $0 < r < s < L$, where L is the number of lags.

We define $Z(t)$ as the standardized observations, obtained via the following formula:

$$Z(t) = \frac{x(t) - m_x}{S_x}$$

for each $t = 1, 2, \ldots.., n$ where m_x, s_x are the sample mean and sample standard deviation, respectively, of a window.

The sample correlation is given by

$$C_{xxx}(r) = (n - r)^{-1/2} \sum_{t=1}^{n-r} z(t)z(t+r)$$

and the sample bicorrelation (r,s) by

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[2] $K = \frac{1}{T} \sum_{t=1}^{T} \left(\frac{X_t - \bar{X}}{\hat{s}} \right)^4$. For a normal distribution, this statistic is equal to 3. Other distributions may be leptokurtic (K>3) or platykurtic (K<3).

[3] $JB = \frac{N - k}{6} \left(S^2 + \frac{1}{4} (K - 3)^2 \right)$; H_0= Stock Returns ~ Normal; Under H_0= JB~χ^2_2

[4] For a mathematical derivation, see Hinich (1996) and Hinich and Patterson (2005).

$$C_{xxx}(r,s) = (n - s)^{-1} \sum_{t=1}^{n-s} z(t)z(t+r)z(t+s)$$

for $0 \le r \le s$. The H test statistic used to study the non-linear dependencies within a window is defined as

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

where

$$G(r,s) = (n - s)^{1/2} C_{xxx}(r,s) .$$

The number of lags L for the H test statistics is specified as $L = n^b$ on the interval $0 < b < 0.5$, where b is a parameter chosen by the user. On the basis of Monte Carlo simulations, Hinich and Patterson (1996) recommend that $b = 0.4$ in order to increase the power of the test while ensuring the approximation so obtained is valid according to asymptotic theory.

IV. Empirical results

Before checking for episodes of non-linearity, we first eliminated linear dependencies by applying an $AR(p)$ model to the original series. This step was taken to ensure any rejection of the null hypothesis of white noise would be due exclusively to non-linear dependencies.

To conduct the test we divided the sample into a set of non-overlapping windows each containing 25 observations. The length of the window must be long enough for the test to be valid but short enough that the data-generating process remains unaffected by this division.

<Insertar Tabla 3>

Table 3 displays the results obtained by applying the bicorrelation test to the adjusted $AR(p)$ model residuals for each returns series. They show that the majority of Chilean companies studies show evidence of non-linearity, the exceptions being BCI, ENDESA and ENERSIS, thus demonstrating that returns in the Chilean stock market do not support the weak-form efficient market hypothesis. Note, however, that the non-linearities are not temporally stable and much of the time behave like a white noise process in which the non-linearity appears infrequently and for brief periods only.

Upon closer observation of Table 3, we may identify four periods in which at least two companies display non-linearity simultaneously. Table 4 enumerates the non-linear periods common to more than one firm.

<Insertar Tabla 4>

The question that naturally arises in the light of these results is whether there is some common factor behind this behavior. Although this article is not primarily concerned with discovering the events that might explain the non-linear episodes, a general review of the period under study was nevertheless conducted, turning up a number of occurrences that may be considered relevant. Regarding the episode of May 2000, the Central Bank of Chile announced at that time the repeal of regulations imposing minimum lock-in periods on short-term foreign capital flows in an effort to liberalize the domestic market and strengthen its integration with international markets. The most important event related to the non-linear window in 2001 was without doubt the attacks of September 11. As for 2002, the reform of the private pension fund setup began with the launch of the Multifunds during the first half of the year. And the non-linear episode of 2005 coincided with the reintroduction in the Chilean National Congress of a series of capital market reforms dealing with matters such as risk capital and the loosening of restrictions on pension fund investments in variable-income instruments.

In view of these results, the application of alternative tests to corroborate the presence of non-linearity would be useful. This task will be taken up in the next section.

V. Alternative tests of non-linearity

The alternatives we chose for verifying the results of the Hinich bicorrelation test on non-linearity were the BDS test and Engle's LM test, both widely utilized in the literature. The BDS test, developed by Brock, Dechert and Scheinkman (1996), is a portmanteau statistic that checks for non-linear dependencies in a data series. The null hypothesis tests whether the elements in the series are independent and identically distributed. In this application of the test we used an epsilon value of 0.7 and a maximum dimension (m) of 6.

As for the LM test, it was developed by Engle (1982) to detect ARCH disturbances. A Lagrange multiplier-type test, it is based on the R^2 of an auxiliary regression that in this case can be defined as $\varepsilon^2 = \alpha_0 + \sum_{s}^{p} \alpha_s \varepsilon_{t-s}^2 + v_t$ under the null hypothesis of a linear generator mechanism for ε^2. NR^2 for this regression is asymptotically $\chi^2(p)$. The test was applied using up to four lags for each variable.

<Insertar Tabla 5>

Table 5 presents the results of the non-linearity tests in terms of p-values. They provide broad confirmation of the results obtained on the Hinich bicorrelation test. The BDS test affords clear evidence of non-linear behavior in the majority of the series with the exception of the one for ENTEL. Engle's LM test indicates the presence of ARCH disturbances in each series. The Hinich test used with a windowed procedure is more efficient than either of these two given that it offers more detailed information and successfully detects the presence of non-linear phenomena in a large sample of data. This latter characteristic is due to the division into subsamples or windows, enabling the capture of episodic non-linearities that might otherwise be dissipated in extensive data series samples.

VI. Conclusions

This article has presented an empirical test of the nonlinear behavior of the Chileanstock market. Twelve major companies included in a share price index published by the Santiago Stock Exchange were analyzed using the Hinich bicorrelation test. Two further tests, BDS and Engle's LM, were employed to ratify the presence of non-linear behavior in the data series, producing results that support those given by Hinich.

These findings confirm the presence of non-linear structures and thus constitute evidence tending to reject the notion that the studied stock returns follow a random walk. However, the non-linear serial dependencies were shown to be episodic, with most of the returns series exhibiting statistically significant non-linear periods that were few and short-lived followed by long periods during which returns followed a white noise process.

The rejection of the weak-form efficient market hypothesis and the presence of non-linear behavior imply the existence of opportunities for investors to exploit information asymmetries and obtain abnormal returns. Nevertheless, the episodic nature of the non-linearities would in practice make it difficult to exploit the potential for returns predictability.

Finally, we note that an interesting topic for future research would be to further investigate which events may have affected companies as a whole and may explain the appearance of non-linear windows in the Chilean stock market. Such efforts would broaden our understanding of this market and position investors to take better advantage of inefficiencies and imperfections in market information flows.

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TABLE 1: Companies by period and number of data items.

	Start date	End date	Data items	Relative weight
IPSA (Index)	05/01/1998	15/12/2006	2,256	NA
ANTARCHILE	08/01/1998	18/12/2006	1,942	4.13
BCI	07/01/1998	18/12/2006	1,976	1.85
BSANTANDER	05/01/1998	15/12/2006	2,216	5.96
CHILE	07/01/1998	15/12/2006	2,114	3.49
CHLECTRA	05/01/1998	07/07/2006	1,784	1.82
CMPC	05/01/1998	15/12/2006	2,222	3.84
COPEC	05/01/1998	15/12/2006	2,234	8.71
ENDESA	05/01/1998	15/12/2006	2,231	6.59
ENERSIS	05/01/1998	15/12/2006	2,229	5.71
ENTEL	05/01/1998	15/12/2006	2,229	1.76
FALABELLA	05/01/1998	15/12/2006	2,215	4.93
LAN	06/01/1998	15/12/2006	2,114	1.77

TABLE 2: Statistical characteristics.

	ANTARCHILE	BCI	BSANTANDER	CHILE	CHILECTRA	CMPC
Mean	0.0012	0.0010	0.0007	0.0006	0.0004	0.0008
St. Dev.	0.0249	0.0131	0.0167	0.0173	0.0254	0.0159
Maximum	0.5130	0.1093	0.2226	0.1446	0.3982	0.2090
Minimum	-0.4960	-0.1136	-0.2142	-0.1335	-0.3964	-0.2021
Skewness	1.4568	-0.0023	0.3357	0.3793	-0.1158	0.2291
Kurtosis	203.4160	12.3680	32.2199	14.2727	132.7161	29.3352
J-B	3,250.834	7,225.476	78,875.79	11,243.82	1,250.757	64,229.96

	COPEC	ENDESA	ENERSIS	ENTEL	FALABELLA	LAN
Mean	0.0008	0.0004	-0.0001	0.0006	0.0006	0.0008
St. Dev.	0.0157	0.0362	0.0198	0.0339	0.0186	0.0230
Maximum	0.0984	0.5028	0.1788	0.9473	0.1128	0.1775
Minimum	-0.0673	-0.4980	-0.1762	-0.9565	-0.1178	-0.1580
Skewness	0.3145	0.0488	0.3418	-0.3123	0.4730	0.1518
Kurtosis	5.7742	137.0208	12.4098	556.7490	7.7190	12.15
J-B	753	1,669	8,266	28,479	2,041	7,381

TABLE 3: Results of the Hinich bicorrelation test using windowed test procedure.

	IPSA	ANTARCHILE	BCI	BSANTANDER	CHILE	CHILECTRA	CMPC	COPEC	ENDESA	ENERSIS	ENTEL	FALABELLA	LAN
AR(p) MODEL	AR(1)	AR (1)	AR (1)	AR (0)	AR (2)	AR (2)	AR (3)	AR (0)	AR (2)	AR (0)	AR (2)	AR (0)	AR (1)
NO. OF WINDOWS	90	77	79	88	84	71	88	89	89	89	89	84	84
SIGNIFICANT H WINDOWS	0 (0.0%)	4 (5.2%)	0 (0%)	4 (4.5%)	4 (4.8%)	1 (1.4%)	3 (3.4%)	3 (3.4%)	0 (0%)	0 (0%)	6 (6.7%)	5 (6.0%)	1 (1.2%)
DATE	20/08/01 26/09/01	08/01/98 13/03/98		08/06/99 13/07/99	29/06/00 07/08/00	28/11/00 08/01/01	09/02/00 15/03/00	16/03/98 20/04/98			15/01/01 16/02/01	04/05/00 07/06/00	06/01/05 08/02/05
		26/01/99 05/04/99		09/05/00 12/06/00	31/01/01 07/03/01		29/07/04 01/09/04	24/09/01 29/10/01			02/05/01 06/06/01	29/08/01 05/10/01	
		01/10/01 06/11/01		06/10/00 13/11/00	07/01/03 10/02/03		26/07/05 30/08/05	02/05/02 07/06/02			16/07/01 20/08/01	22/05/02 26/06/02	
		28/02/02 04/04/02		01/08/01 06/09/01	06/01/05 08/02/05						21/08/01 28/09/01	18/03/03 24/04/03	
											17/06/03 21/07/03	28/05/04 05/07/04	
											20/01/05 22/02/05		

TABLE 4: Simultaneous non-linear episodes

WINDOW		COMPANY
FROM	TO	
04/05/00	12/06/00	BSANTANDER FALABELLA
01/08/01	29/10/01	BSANTANDER COPEC ENTEL FALABELLA
02/05/02	26/06/02	COPEC FALABELLA
06/01/05	22/02/05	CHILE ENTEL FALABELLA

TABLE 5: Test for non-linear serial dependency

	BDS	ENGLE'S LM
IPSA	0.0000	0.0000
ANTARCHILE	0.0000	0.0000
BCI	0.0000	0.0000
BSANTANDER	0.0000	0.0000
CHILE	0.0000	0.0000
CHILECTRA	0.0000	0.0000
CMPC	0.0000	0.0000
COPEC	0.0000	0.0000
ENDESA	0.0000	0.0000
ENERSIS	0.0000	0.0000
ENTEL	0.9656	0.0000
FALABELLA	0.0000	0.0000
LAN	0.0000	0.0000

Only the P-values are given, under the null hypothesis that the time series is an i.i.d. process.