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Assessing adaptability in stock market indices; The case of Latin America

Evaluación de la adaptabilidad en los índices bursátiles; el caso de América Latina

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Abstract

This paper aims to examine the Adaptive Markets Hypothesis in six Latin American stock market indices. The results of the bootstrapped versions of the Chow-Denning and Brock, Scheinkman, Dechert, and LeBaron independence tests and the Runs test applied to fixed-length moving subsample windows reveal the linear time-varying adaptability of the Argentinian, Brazilian, Chilean, Colombian, Mexican, and Peruvian stock indices, while the evidence of non-linear adaptability is not strong. The six indices also adapt to specific market conditions, although this varies with each market. There is evidence of adaptability in Latin American stock indices, but investors should view each market independently.

JEL Code: C58, G14, G15
Keywords: adaptive markets hypothesis; return predictability; market conditions; Latin American stock markets

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Resumen

Este artículo tiene como objetivo examinar la Hipótesis de los Mercados Adaptativos en seis índices bursátiles de América Latina. Los resultados de las versiones con remuestreo de las pruebas de independencia Chow-Denning y Brock, Scheinkman, Dechert y LeBaron, así como la prueba de corridas aplicada a ventanas de sub-muestras móviles de longitud fija, revelan la adaptabilidad lineal variable en el tiempo de los índices bursátiles de Argentina, Brasil, Chile, Colombia, México y Perú, en tanto que la evidencia de adaptabilidad no lineal no es sólida. Los seis índices también se adaptan a condiciones de mercado específicas, aunque esto varía en cada mercado. Existe evidencia de adaptabilidad en los índices bursátiles de América Latina, pero los inversionistas deben considerar cada mercado de forma independiente.

Código JEL: C58, G14, G15
Palabras clave: hipótesis de los mercados adaptativos; previsibilidad de la rentabilidad; condiciones de mercado; mercados bursátiles latinoamericanos

Introduction

Over the last five decades, the Efficient Market Hypothesis (EMH) has been one of the most influential and examined theories in finance. The EMH, initially suggested by Bachelier (1900) and later formalized by Fama (1970), asserts that financial asset prices are unpredictable because they change randomly to incorporate all relevant available information. This rapid adjustment in asset prices prevents investors from consistently benefiting from higher returns. In its weak form, market efficiency implies that, at any point in time, asset prices reflect all information about historical prices and trading volumes (Roberts, 1967). If profits could be made by predicting prices from historical data, arbitrage would quickly eliminate such profits. Weak-form efficiency has become the most tested form of the hypothesis in the empirical literature. Initial studies on the EMH reported evidence that supported that hypothesis (Fama, 1965, 1970; Roberts, 1967; Samuelson, 1965). However, the findings of subsequent research challenged market efficiency and evidenced that stock returns do not follow a random walk (Fama & French, 1988; Jegadeesh & Titman, 1993; Lo & MacKinlay, 1988).

Several studies from the standpoint of behavioral finance opposed the ideas behind market efficiency (De Bondt, 2000; De Bondt & Thaler, 1985; Shiller, 1980). While the EMH considers that investors are consistently rational and securities are valued accordingly, behavioral finance claims that investors are not always rational and that their emotions, incentives, and biases play a role in their decision-making process (Barberis & Thaler, 2003).

Grossman & Stiglitz (1980) assert that a perfectly efficient market is not possible since if prices fully reflect all available information, investors will not have any incentive to acquire costly information. Reflecting on arguments such as these, Shiller (2003) concludes that academic finance no longer considers the EMH to be proved beyond doubt.

Lo (2004) proposed the Adaptive Markets Hypothesis (AMH) as a new explanation for the dynamics of stock prices which tries to reconcile the conflicting views of the EMH and behavioral finance. The notions behind the AMH come from evolutionary biology, evolutionary psychology, behavioral ecology, bounded rationality of economics, and complex systems (Lim & Brooks, 2006). The AMH considers that market efficiency is not an all-or-nothing situation but a time-varying condition. Specifically, this theory suggests that market efficiency adjusts depending on the changing nature and number of market participants, profit opportunities, and market conditions (Lo, 2005). Therefore, the AMH implies that periods of efficiency and inefficiency may alternate in a rationally coherent manner.

The main objective of this paper is to study the predictability of stock index returns and examine the implications of the AMH on six Latin American stock markets, namely, Argentina, Brazil, Chile, Colombia, Mexico, and Peru. As a group, these markets represent a significant portion of emerging markets, yet they have received relatively limited research attention. The sample was from January 2000 to December 2020 for all stock markets, except for the Colombian market. For the latter, the study considered the period from January 2008 to December 2020 due to data availability constraints.

So, this research contributes to the current literature on the Adaptive Market Hypothesis (AMH) by examining the evolving efficiency of six emerging stock markets in Latin America. To explore this issue, the study employs both linear and non-linear predictability tests, using two-year fixed-length windows rolled forward by one year. The paper also contributes to the exploration of the AMH by examining changes in return predictability across various market conditions in these Latin American stock market indices.

The rest of the paper is structured as follows: section 2 briefly reviews the relevant literature, section 3 describes the data and explains the methodology used in the research, section 4 presents the empirical results, and section 5 discusses the results and concludes the paper.

Literature review

From the EMH's point of view, a market is efficient when it is not possible to obtain abnormal returns when trading on the available information (Fama, 1970). However, behavioral economists question the notion of immediate and complete information absorption and the idea of unfailing rationality in investors' decision-making process. The basis of their criticism is the argument that these assumptions of the EMH do not match human behavior (Almudhaf, Aroul, & Hansz, 2020).

Some concepts developed in evolutionary psychology and cognitive neurosciences may help reconcile the conflicting standpoints of the EMH and behavioral finance (Lo, 2004). Simon (1955, 1982) proposed and developed the idea of bounded rationality, meaning that cognitive constraints may restrict people's decisions. Usually, individuals do not seek a rational or optimal solution but a satisfactory answer. The AMH proposes a new framework that applies evolutionary dynamics to extend the idea of satisficing (Lo, 2004).

Rosini & Shenai (2020) found that from 2007 to 2016, the FTSE100 and FTSE250 indices of the London Stock Exchange experienced alternating periods from efficiency to inefficiency in support of the AMH. Boya (2019) analyzed the AMH in the French stock market from 1988 to 2018 through a rolling variance ratio test and concluded that the French stock market presents alternating stages of efficiency and inefficiency, as implied by the AMH.

Rönkkö, Holmi, Niskanen, & Mättö (2024) explore the OMXH25 index of the Finnish stock market between May 1988 and February 2019, finding clear evidence that the AMH provides a better description of its returns than the EMH. The authors highlight that, according to their results, the Finnish stock market became more efficient after lifting all restrictions on foreign ownership, which they deem as evidence supporting the AMH. Furthermore, Noda (2016) studied the AMH in the TOPIX and TSE2 indices of the Japanese stock market from 1961 to 2015, applying a time-varying model approach. The research found that the degree of market efficiency changes over time in the two indices, which supports the AMH. Ito, Noda, & Wada (2016) developed a non-Bayesian model that considered the concept of time-varying market efficiency and examined whether the U.S. stock market evolves across time. They concluded that the degree of market efficiency in the U.S. has cyclical fluctuations with periodicity from 30 to 40 years.

To explore the AMH in the stock markets of the United States, the United Kingdom, and Japan, Urquhart & Hudson (2013) applied both linear and non-linear tests. The study reports that, over the long run, the AMH describes the behavior of stock returns better than the EMH. Urquhart & McGroarty (2016) used the bootstrapped version of the Chow-Denning variance ratio test and the BDSL test (Brock, Scheinkman, Dechert, & LeBaron, 1996) to study the S&P 500, FTSE 100, NIKKEI 225, and EURO STOXX 50 indices from January 1990 to May 2014. Their results show that, as proposed by the AMH, the return predictability of such indices varies over time and that each market adapts differently to specific market conditions. The results of the automatic portmanteau and automatic variance ratio tests, using a rolling window approach, applied by Kim, Shamsuddin and Lim (2011), provide strong evidence of time-varying return predictability of the Dow Jones Industrial Average (DJIA) index from 1900 to 2009. Specifically, the authors conclude that, as the AMH suggests, return predictability is driven by changing market conditions.

Research related to the AMH has also focused on emerging stock markets. Mandaci, Taşkin, & Ergün (2019) examined the implications of the AMH on three Turkish stock market indices between January 2002 and April 2017, with conflicting findings. The results of the variance ratio test using a two-year rolling window approach suggest that the Turkish stock market remains inefficient across all time-windows, denying the AMH. On the other hand, the BDSL results suggest that Turkish market indices' returns generally cannot be predicted, although there are instances where predictability does emerge. Nevertheless, the authors conclude that their findings support the existence of AMH since the structure of the data is not linear.

Other research papers on the AMH have also considered emerging stock markets from Africa, Asia, and Eastern Europe (e.g., Adaramola & Obisesan, 2021; Hiremath & Narayan, 2016; Lekhal & El Oubani, 2020; Shi, Jiang, & Zhou, 2017). However, only a few studies include Latin American markets. For example, Cruz-Hernández & Mora-Valencia (2023) found that the behavior of five Latin American stock indices are in line with the postulates of the AMH. They reported alternating stages of efficiency and inefficiency, supporting the notion that market anomalies and efficiency can coexist as per AMH. In this regard, Villarreal-Samaniego & Santillán-Salgado (2023) report the presence of the Day-of-the-Week effect in three out of six Latin American stock indices analyzed, with its presence varying across different market conditions.

In their study, Souza & Silva (2021) used Hurst's exponent test to examine the link between economic-political uncertainty and market efficiency in twenty-one countries, including Brazil and Mexico. The research concludes that the economies under consideration may be adapting to uncertain environments, aligning with the principles of the AMH. Similarly, the results reported by Sierra, Duarte, & Rueda (2015) show that the efficiency of the Colombian is time-varying, supporting the AMH.

While much of the attention in the AMH literature focuses on stock markets, especially those in developed economies, there has been a growing interest in exploring its applicability in other financial markets, such as cryptocurrencies (e.g., Khuntia & Pattanayak, 2022; López-Martín, 2023) and foreign exchange (e.g., Almail & Almudhaf, 2017; Phiri, 2022). These studies also report evidence for the AMH in these markets.

Methodology

Data

The data for the stock indices of Argentina (MERVAL), Brazil (BOVESPA)[1], Chile (IPSA), Mexico (IPC), and Peru (ISBVL) comprises 21 years, from January 2000 to December 2020. For the Colombian

[1] Several authors refer to the Brazilian stock market index as "IBOVESPA" (Zhang, Lai and Lin, 2017; Kinateder, Weber and Wagner, 2019), in this research it is called "BOVESPA" following other authors (Horta and Ziegelmann, 2018; Nguyen *et al.*, 2021).

stock index (COLCAP), the data includes 13 years, from January 2008 to December 2020, due to data availability[2]. The source of the data was Economatica, a financial database, and Investing.com.

The equation used to obtain the daily returns (r_t) of each stock index was:

$$r_t = \left(\ln(P_t) - \ln(P_{t-1})\right) \times 100 \tag{1}$$

In Equation (1), r_t is computed as the first difference of the logarithm of the closing price of an index on a trading day ($\ln(P_t)$) with respect to the logarithm of its closing price the previous trading day ($\ln(P_{t-1})$).

Classification of the data

In its weak form, market efficiency implies that the analysis of past returns is useless to predict future returns since asset prices follow a random walk. This study uses three tests for independence to examine whether Latin American stock indices' returns move in a random walk. The first two tests evaluate linear dependence, while the third assesses non-linear dependence. The analysis comprises two-year rolling windows with a one-year step size to provide enough observations. This procedure extends from January 2000 to December 2020 and generates 20 windows for each index, except the COLCAP, where the process starts in January 2008 and produces 12 windows.

The study also applies the three tests of independence to different market conditions. Following Fabozzi & Francis (1977), this research classifies the series into Up or Down periods. Up periods are those months in which the average return was non-negative and Down periods are those months with a negative average return. Although this procedure provides an exhaustive and mutually exclusive categorization, it does not consider market trends. So, this study also categorizes the sample into normal, bull, and bear conditions, according to the classification proposed by Klein & Rosenfeld (1987). A month is classified as a substantial market mover when the absolute value of the monthly return of a particular index exceeds one-half of the index's standard deviation of monthly returns over the corresponding full sample. The sample is then divided into bear, normal, and bull categories based on the trend. For example, if the return of an index is either normal or declines during a specific month while it shows a bullish behavior in the

[2] The COLCAP replaced the IGBC as the main index of the Colombian stock market in November 2013 (Sierra, Duarte and Rueda, 2015). Since differences in methodology, components, and data collection techniques make these two indices dissimilar, the study does not attempt to extrapolate the behavior of the COLCAP based on the IGBC.

surrounding months, this month is considered bullish. On the other hand, if the index's return is normal or increases in a particular month while it presents a bearish behavior in the contiguous months, this month is said to be bearish. Therefore, each market type must contain two or more successive substantial movements.

Multiple variance ratio test

The variance ratio (VR) test, introduced in the seminal work by Lo & MacKinlay (1988), is the most used parametric method for examining linear predictability (Hoque, Kim, & Pyun, 2007). The basic idea behind the VR test is that if the price of an asset follows a random walk, then the variance of the k-period difference is equal to k times the variance of the one-period variance. The null hypothesis of the test is that the variance ratio equals 1 for all k's. The variance ratio test VR(k) for r_t, the return or the asset at time t (t = 1, 2, 3 ... T), with a holding period k is:

$$VR(k) = \sigma_k^2 / k\sigma^2 = 1 + 2\sum_{j=1}^{k-1}\left(1 - \frac{j}{k}\right)\rho_j \tag{2}$$

where σ_k^2 is the variance of the k-period return, σ^2 is the variance of a one-period return, and ρ_j is the autocorrelation of r_t of order j. Values for VR(k) less than 1 denote mean reversion or negative serial correlations, while values greater than 1 indicate positive serial correlations (Urquhart & McGroarty, 2016).

Heteroskedasticity, a common feature of financial time series, may cause the rejection of the hypothesis of return independence. To address this issue, Lo & MacKinlay (1988) propose a heteroskedastic robust test:

$$Z^*(k) = \frac{VR(k) - 1}{\phi^*(k)^{1/2}} \tag{3}$$

which follows a standard normal distribution asymptotically under the null hypothesis that VR(k) = 1; where:

$$\phi^* = \sum_{j=1}^{k-1}\left(\frac{2(k-j)}{k}\right)^2 \delta(j)\,; \tag{4}$$

$$\delta(j) = \left(\sum_{t=j+1}^{T} (r_t - \hat{u})^2 (r_{t-j} - \hat{u})^2\right) \Big/ \left(\sum_{t=j+1}^{T} (r_t - \hat{u})^2\right)^2 ;$$

(5)

A drawback of the conventional VR test is that the values of k are selected subjectively (Ely, 2011). Chow & Denning (1993) point out that failing to control test size for multiple comparisons implies multiple testing, which leads to an over-rejection of the null hypothesis. Thus, the test for the null hypothesis should be conducted as a joint test for VR(k) = 1 for multiple values of k. The Chow-Denning (CD) test is a multiple VR test where only the highest absolute value of VR(k) in a set of m variance ratio statistics is considered. The heteroskedastic CD test statistic is:

$$CD = \sqrt{T} \max_{0 \le j \le m} \left| Z^*(k_j) \right|$$

(6)

where $Z^*(k_j)$ is defined as in Equation (3). The CD test follows the studentized maximum modulus (SMM) distribution with m parameters and T degrees of freedom.

Urquhart & McGroarty (2016) claim that the VR test is misleading in small samples since it is based on asymptotic theory. So, this research applies the wild bootstrapped VR test proposed by Kim (2006) to improve the small sample properties of the CD statistic. This method requires computing the individual and joint VR test statistics on samples of T observations, formed by weighting the original data by random variables with a mean of zero and a variance of 1 and using the results to create bootstrap distributions of the test statistics. The bootstrapped p-values come from the fraction of repetitions falling outside the bounds defined by the estimated statistic.

Runs test

The Runs test is a non-parametric method frequently used to examine the randomness of returns[3]. A run is defined as a series of positive or negative values, while the number of positive or negative values is the length of the run. If the number of Runs is close to its expected value, then the data series is generated by a random process. The expression to determine the expected number of Runs (ER) is:

$$ER = \frac{2PN}{P + N} + 1$$

(7)

[3] Although this test is usually categorized as linear, Urquhart & Hudson (2013) argue that it has the capability to identify non-linear dependence as well.

Where P is the number of positive Runs and N is the number of negative Runs. The variance of Runs is computed as:

$$\sigma^2 = \frac{2PN(2PN - P - N)}{(P + N)^2(P + N - 1)} \tag{8}$$

If the *z*-value is less than the critical values, the test fails to reject the null hypothesis of independence of the series. Moreover, it is possible to assess the randomness of the return series by examining the duration of the Runs distribution because the sample is not independent if it comprises too few or too many Runs.

BDSL test

The BDSL test, developed by Brock et al. (1996), is a portmanteau test for non-linear dependence in a series. The null hypothesis of the test is that a time series sample comes from an independent and identically distributed (i.i.d.) data generating process. Consequently, failing to reject the null hypothesis agrees with market efficiency. Specifically, Brock et al. (1996) show that:

$$W_{m,n}(\varepsilon) = \sqrt{n}\frac{T_{m,n}(\varepsilon)}{V_{m,n}(\varepsilon)} \tag{9}$$

where $W_{m,n}(\varepsilon)$ is the BDSL test statistic, n is sample size, m is embedding dimension and ε is the maximum difference between pairs of observations considered in estimating the correlation integral. $T_{m,n}(\varepsilon)$ is the difference between the dispersion of the observed data series in some spaces following an i.i.d. process would generate in these spaces $(C_{m,n}(\varepsilon) - C_{1,n}(\varepsilon))$ and has an asymptotic normal distribution with zero mean and variance $V_m^2(\varepsilon)$.

The selection of ε and m is relevant for the BDSL test. As the literature suggests, ε is a proportion of the standard deviation of the series[4]. For the relevant embedding dimension, m, this research sets the value from two to five considering that previous studies suggest a range of values from two to ten for this parameter (Hiremath & Kumari, 2014; Mandaci et al., 2019; Urquhart & Hudson, 2013).

The literature also stresses the importance of whitening the returns through an AR-GARCH specification (Mandaci et al., 2019; Obalade & Muzindutsi, 2018; Urquhart & McGroarty, 2016) to

[4] Specifically, in this study ε correspond to 1.5 standard deviations.

remove any non-linear dependence related to the conditional heteroskedasticity. Following Lim & Hooy (2013), this research fits AR(p) models to remove the linear correlations with the optimal lag length determined when the standardized residuals are no longer correlated up to 10 lags according to the Ljung-Box Q-statistic. The study examines the residuals for i.i.d. using the bootstrapped BDSL test, such that:

$$r_t = \beta_0 + \sum_{i=1}^{p} \beta_i r_{t-i} + \varepsilon_t \tag{10}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \sigma_{t-1}^2 \tag{11}$$

where r_t is the return series, ε_t stands for the residual of the mean equation, and σ_t^2 represents the conditional variance of the residual. Therefore, if the BDS test finds the AR-GARCH filtered returns have significant dependence, index returns are non-linearly predictable.

Results

Time-varying linear predictability

Table 1 shows the results of the Chow-Denning and Runs tests for the complete sample for the six indices. The p-values of both tests show that the returns of the IPSA, COLCAP, IPC, and ISBVL are predictable, while the BOVESPA is efficient. The outcomes for the MERVAL remain inconclusive.

Panels A through E in Figure 1 present the p-values of the CD and Runs tests across time for the two-year rolling windows for each of the indices. The statistical significance of such tests is assessed considering p-values. Specifically, when the p-value is 0.05 or more, the corresponding test fails to reject the null hypothesis of independence. Following Urquhart & Hudson (2013), in this study, a market is considered adaptive if returns have undergone more than two different stages of statistical dependence (e.g., a transition from independence to dependence and then back to independence).

Table 1
Chow-Denning variance ratio test and Runs test for the full sample

	Chow-denning test				Runs test	
Market index	Joint test	VR statistic	df	p-value	No. of runs	p-value
Merval	Max |z| (at period 16)	1.6314	5142	0.232	2488	0.021
Bovespa	Max |z| (at period 9)	1.3851	5198	0.329	2651	0.142
Ispa	Max |z| (at period 2)	4.3646	5232	0.001	2296	0.000
Colcap	Max |z| (at period 4)	2.5260	3168	0.030	1475	0.000
Ipc	Max |z| (at period 2)	4.5111	5282	0.000	2501	0.000
Isbvl	Max |z| (at period 2)	4.4109	5256	0.001	2339	0.000

Source: Author's own

Panel A shows the p-values of the CD and Runs tests for the MERVAL. Both tests indicate that the Argentinian stock market remained unpredictable throughout most of the 2000-2020 period. However, inefficiency emerged in specific periods, such as 2011-2012 according to the CD test, or more recently, in 2017-2018 based on the Runs test. These linear results imply that the MERVAL goes through intervals of efficiency and inefficiency, supporting the AMH.

In Panel B, the rolling window analysis exposes BOVESPA's continued unpredictability from 2000 to 2020, which mirrors the results observed during the full sample period. The CD test results consistently suggest efficiency across all subperiods, whereas the Runs test points to inefficiency only in the last subperiod. While this may suggest the emergence of an adaptive market, it does not conclusively support the AMH in the Brazilian market.

The results of the CD and Runs tests in Panel C reveal predictable returns for the IPSA index during 2002-2006 and 2015-2016. Moreover, according to both tests, a total of six shifts in significance occurred in the Chilean index across the full sample period. These results, as commonly interpreted in AMH literature, strongly support the hypothesis.

In Panel D, results for the COLCAP show inefficiency from 2013 to 2016 according to the CD test. The Runs test suggests predictability in 2008-2009 and 2014-2015. The combined linear tests results imply only two different stages of statistical dependency for the COLCAP returns, which provides limited evidence for the AMH. Nevertheless, this finding should be taken cautiously considering the smaller number of observations available for the COLCAP.

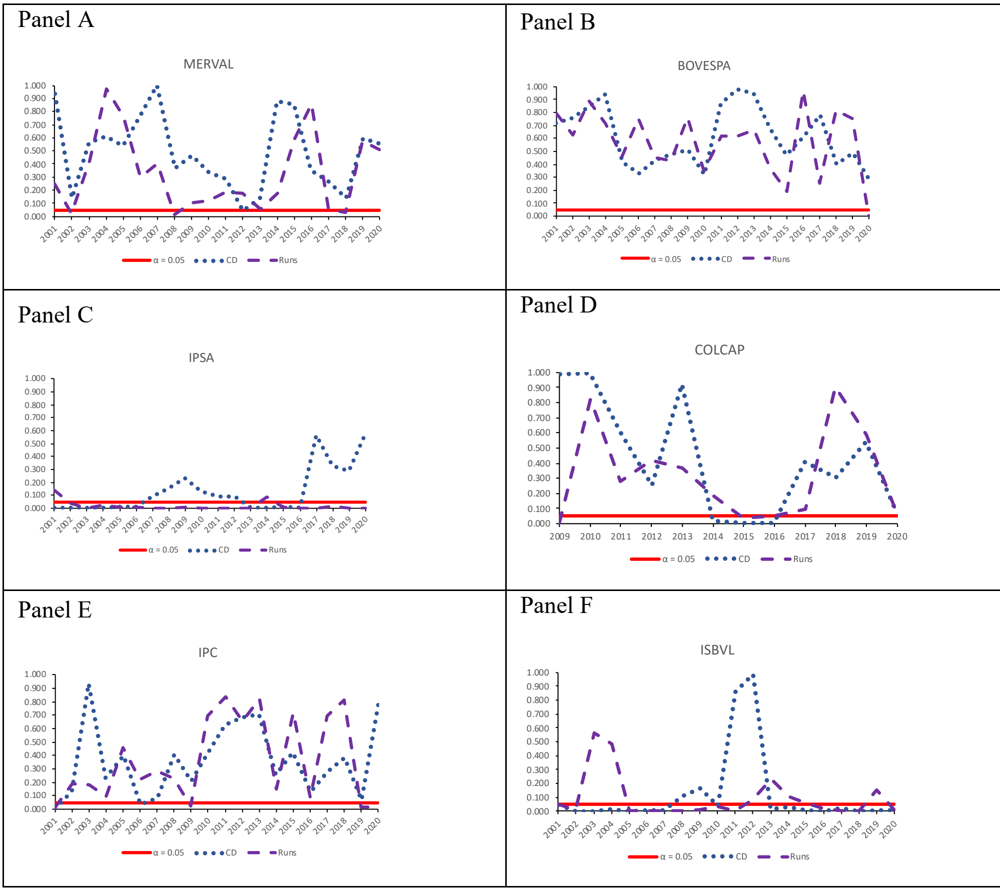

Figure 1. Chow-Denning variance ratio joint-test and Runs test *p*-values across time (two-year windows).

Source: Author's own

The results in Panel E suggest the IPC was efficient throughout most of the 2000-2020 period. However, both the CD and Runs tests display predictability during the Dot-com crisis in 2000-2001. Likewise, the Runs test indicates inefficiency during the Great Recession in 2008-2009 and the COVID-19 pandemic in 2018-2020. While the CD and Runs tests suggest 3 and 4 predictability stages in the IPC, respectively, only the early 2000s period appears robust. Therefore, the IPC seems to be predictable during crisis episodes from the linear tests' point of view.

Panel F exhibits the time-varying independence behavior for the ISBVL. The rolling-window analysis reveal that the ISBVL was mostly inefficient from 2000 to 2020, consistent with the findings for the entire sample period. However, the variance-ratio and Runs tests robustly indicate that the Peruvian stock index's returns experienced eight efficiency shifts over this period.

Time-varying Non-linear predictability

Table 2 displays the whole period BDSL results for the six market indices for dimensions 2 to 5. In contrast with the results reported in Table 1, the returns of the IPSA, COLCAP, IPC, and ISBVL are efficient. Furthermore, the MERVAL is unpredictable at all BDSL dimensions except one, while the BOVESPA is unpredictable at only one dimension.

Panels A through F in Figure 2 show the minimum p-values from the four-dimension sizes of the BDSL test through the two-year rolling window analysis described earlier. If the minimum p-value for the four sizes of m turns out to be significant, it is reasonable to conclude non-linear dependence in the returns since there is one model that could potentially predict such returns' dynamics. The study considered a confidence interval of 95% to evaluate the statistical significance of the results.

Table 2
BDSL test for the full sample

Dimension	BDS statistic	Std. error	Z-statistic	p-value	Dimension	EDS statistic	Std. error	Z-statistic	p-value
		Merval					Colcap		
2	-0.0026	0.0011	-2.3792	0.0140	2	-0.0008	0.0014	-0.5480	0.6224
3	-0.0023	0.0018	-1.2432	0.1940	3	-0.0008	0.0024	-0.3282	0.8048
4	-0.0032	0.0023	-1.3699	0.1780	4	-0.0002	0.0030	-0.0735	0.9968
5	-0.0038	0.0025	-1.4911	0.1260	5	-0.0011	0.0033	-0.3388	0.7664
		Bovespa					Ipc		
2	-0.0037	0.0009	-3.9039	0.0000	2	-0.0004	0.0010	-0.3808	0.7744
3	-0.0041	0.0015	-2.6659	0.0100	3	0.0005	0.0017	0.3455	0.6896
4	-0.0040	0.0019	-2.1220	0.0440	4	0.0013	0.0021	0.6047	0.5072
5	-0.0037	0.0020	-1.8077	0.0700	5	0.0015	0.0023	0.6466	0.4984
		Ipsa					ISBVL		
2	-0.0002	0.0010	-0.1770	0.9080	2	0.0004	0.0011	0.3491	0.6824
3	0.0002	0.0015	0.1137	0.8500	3	0.0009	0.0018	0.5067	0.5800
4	0.0003	0.0020	0.1485	0.8540	4	0.0005	0.0022	0.2728	0.7560
5	0.0002	0.0021	0.0845	0.8980	5	0.0004	0.0024	0.1657	0.8424

Source: Author's own

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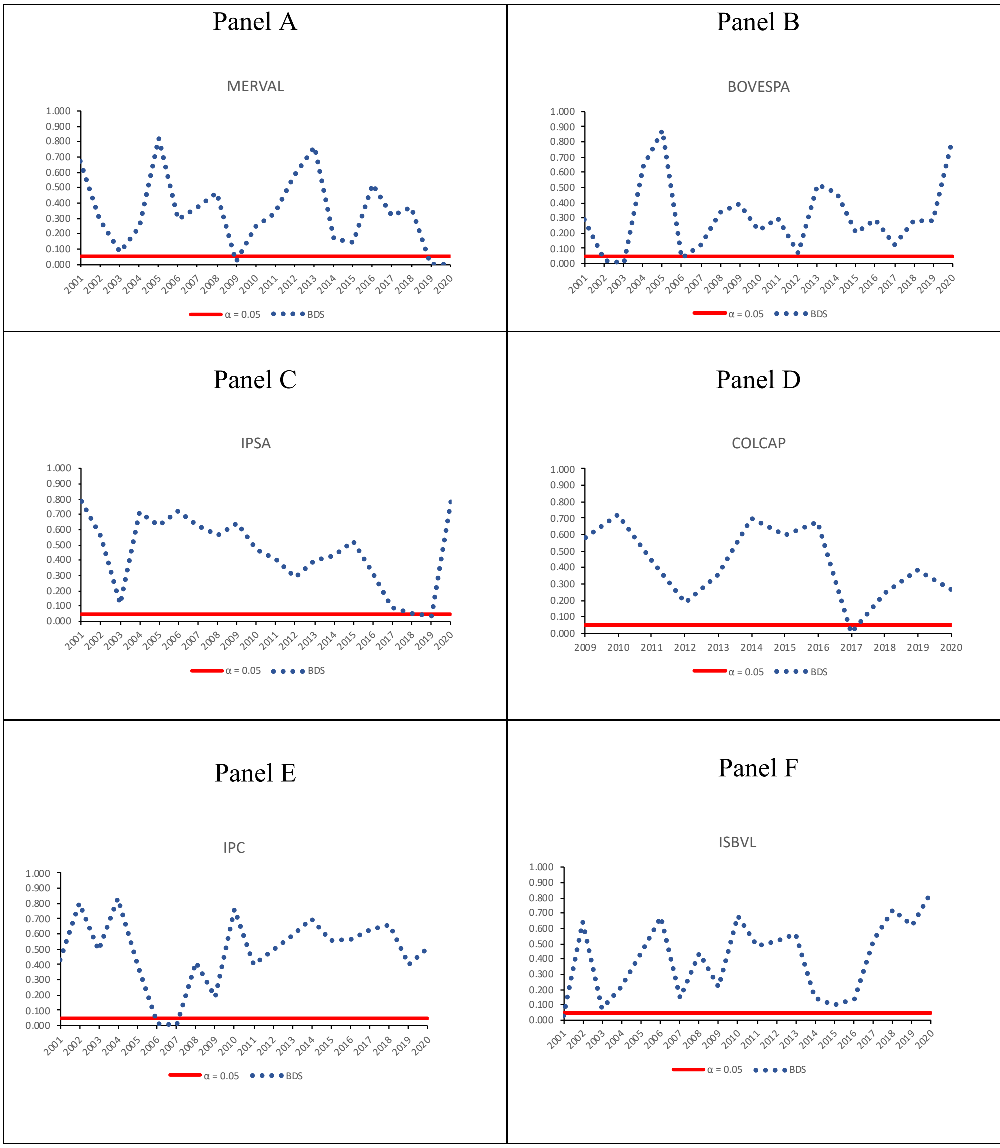

Figure 2. BDSL test *p*-values across time (two-year windows).

Source: Author's own

The outcomes in Figure 2 indicate that most of the BDSL test p-values of the six stock market indices were insignificant. Thus, there is an absence of non-linear dependencies in the returns of the indices for most of the corresponding complete periods examined. Nonetheless, there were several exceptions to this general pattern. The BOVESPA and MERVAL, respectively, displayed 4 and 3 shifts between efficiency and inefficiency, whereas the COLCAP, IPC, and ISBVL each demonstrated 2 shifts. Contrasting with the corresponding linear results, the ISBVL transitioned from inefficiency in the first rolling window to efficiency in the subsequent subperiods.

This study also examines the relative efficiency of the six Latin American stock indices considering the three tests for returns predictability. Table 3 shows the percentage of each test statistic that does not reject the null hypothesis at the 5% significance level, following Smith (2012).

According to Table 3, the IPSA and ISBVL appear to be the least efficient, with an average of only 50% of p-values failing to reject the null hypothesis for both linear and non-linear tests. Conversely, the BOVESPA index stands out as the most efficient, with an average of 93.3% of p-values failing to reject the null hypothesis, followed by the MERVAL at 88.3%. Interestingly, these indices also exhibit the lowest percentage of non-rejections of efficiency from the non-linear standpoint. Also, in line with previous findings, Table 3 results indicate significant levels of linear predictability in Latin American stock markets.

Table 3
Relative efficiency. Percentage of test statistics that fails to reject the null hypothesis of market efficiency at the 5% significance level.

	CD	Runs	BDSL	Average
Merval	95.00%	85.00%	85.00%	88.33%
Bovespa	100.00%	95.00%	85.00%	93.33%
Ispa	50.00%	10.00%	90.00%	50.00%
Colcap	75.00%	83.33%	91.67%	83.33%
Ipc	90.00%	80.00%	90.00%	86.67%
Isbvl	20.00%	35.00%	95.00%	50.00%

Source: Author’s own

Return predictability and market conditions

The AMH, as described by Lo (2004), proposes that the predictability of returns varies in response to shifts in market conditions. However, Kim et al. (2011) emphasize that the AMH does not explicitly define specific indicators of these market conditions or expectations between market conditions and return predictability. So, to explore the link between different market conditions and return predictability, the research arranges the data into Up and Down months, in accordance with the categorization by Fabozzi & Francis (1977). It also applies the classification of bull, normal, and bear markets as suggested by Klein & Rosenfeld (1987).

Table 4 describes the p-values of the three predictability measures under different market conditions, revealing mixed results. Some conditions relate to significant predictability for specific stock indices, while others do not. The MERVAL, for example, appears to be robustly predictable under Down and Normal conditions. Similarly, the BOVESPA also exhibits robust predictability during Normal conditions, although not so during Down markets. Instead, the Brazilian market shows predictability during Bull markets and particularly during Up markets.

The results from either the CD or Runs tests suggest inefficiency for IPSA across all market conditions, contrasting with the BDSL model's results. Additionally, the outcomes of CD and BDSL tests imply that the COLCAP is unpredictable irrespective of the state of the market. However, these results are supported by the Runs test only in Normal market conditions.

Table 4
Predictability tests *p*-values for market conditions.

		CD	Runs	BDSL			CD	Runs	BDSL
Merval	Down	0.121	0.006	0.004	Colcap	Down	0.119	0.000	0.646
	Up	0.800	0.621	0.606		Up	0.163	0.048	0.440
	Bear	0.312	0.793	0.004		Bear	0.054	0.016	0.474
	Normal	0.134	0.023	0.014		Normal	0.892	0.188	0.074
	Bull	0.675	0.977	0.406		Bull	0.573	0.005	0.420
Bovespa	Down	0.123	0.287	0.025	Ipc	Down	0.016	0.004	0.482
	Up	0.000	0.005	0.016		Up	0.004	0.043	0.022
	Bear	0.662	0.327	0.008		Bear	0.020	0.007	0.466
	Normal	0.000	0.138	0.036		Normal	0.111	0.118	0.578
	Bull	0.006	0.032	0.366		Bull	0.064	0.164	0.112
Ipsa	Down	0.305	0.000	0.228	Isbvl	Down	0.175	0.000	0.152
	Up	0.000	0.000	0.786		Up	0.000	0.000	0.606
	Bear	0.268	0.000	0.158		Bear	0.104	0.011	0.202
	Normal	0.000	0.000	0.128		Normal	0.000	0.000	0.174
	Bull	0.003	0.000	0.402		Bull	0.046	0.006	0.414

Source: Author's own

The linear results suggest that the IPC is inefficient during Bear, Down, and Up conditions. Furthermore, in the latter, all three predictability measures agree on the Mexican stock index predictability. In the case of the ISBVL, the outcomes of the linear tests consistently imply predictability regardless of the market condition. On the contrary, BDSL results indicate unpredictability under any market condition.

Conclusions

As emerging countries integrate into the global economy and expand their share of global equity markets, they become increasingly important to international investors. These markets offer potential for higher returns and exposure to diverse economic cycles, industries, and asset classes, contributing to risk diversification. Against this background, this study examines the time-varying efficiency of stock index returns in six Latin American markets from 2000 to 2020 and assesses their predictability under various market conditions using the linear Chow-Denning and Runs tests, along with the non-linear BDSL test on pre-whitened returns.

A relevant contribution of the study is the finding that, except for the Brazilian stock index, the other Latin American indices were unpredictable from a non-linear standpoint throughout the entire sample period, supporting the EMH. The BDSL method, which is effective for testing weak-form efficiency with large samples (Roldán-Casas & García-Moreno García, 2022), confirmed this weak-form efficiency. Conversely, the Brazilian stock index showed significant predictability in both non-linear and linear patterns.

While it might be argued that shifts between predictability and unpredictability do not necessarily support the AMH but rather represent evidence against the EMH, Urquhart & Hudson (2013) propose that a market fits the AMH if its returns exhibit three or more changes in their statistical dependence, as discussed earlier. Nonetheless, this study contends that fewer transitions between inefficiency and efficiency imply less frequent adaptation episodes, arguably indicating limited market adaptability. According the non-linear BDSL test, only the MERVAL and BOVESPA indices display more evidence of adaptability with 3 and 4 predictability changes, respectively. The other indices exhibited only 2 predictability fluctuations, except for the ISBVL which shifted from inefficiency to efficiency.

Linear tests suggest that, excluding the BOVESPA and COLCAP, the indices were inefficient around the Great Recession period. This finding aligns with research by dos Santos et al. (2023), which noted an increase in inefficiency during this crisis episode. Market inefficiency instances were fewer between 2010 and 2012, a period when policies to counteract the financial crisis adverse impacts began positively affecting the housing market, lending, and consumer spending. The Mexican stock index was linearly predictable not only during the Great Recession but also during the Dot-com and COVID-19 crises, possibly due to the significant negative effects of these events on the U.S. economy and its strong trade relations with Mexico. Therefore, these changes might be interpreted as markets adapting in the context of bounded rationality during both financial turmoil and stable periods. However, contrary to Cruz-Hernández & Mora-Valencia (2023), this study finds scant evidence of time-varying non-linear dependence for the Latin American indices.

Another important contribution of this study is the analysis of how efficiency varies under different market conditions in Latin American stock indices. In general, except for the MERVAL, linear predictability is observed under Up or Bear market conditions, especially from the perspective of the Runs test, implying excessive optimism among investors. Similarly, except for the BOVESPA, the other indices exhibit linear predictability in Down market conditions, indicating excessive pessimism. These outcomes arguably suggest that investors adjust their trading strategies according to market conditions. Nevertheless, the non-linear BDSL results generally indicate informational efficiency. Interestingly, both linear and non-linear models robustly indicate that the BOVESPA and IPC are predictable under Up market conditions. However, the economic significance of trading strategies derived from this finding remains a subject for more research.

In conclusion, this study finds varying degrees of evidence in favor of the AMH in all Latin American stock indices from the perspective of linear tests. These results are consistent with similar findings in developed markets (e.g., Boya, 2019; dos Santos et al., 2023; Rosini & Shenai, 2020; Urquhart & McGroarty, 2016) and emerging markets (e.g., Lekhal & El Oubani, 2020; Mandaci et al., 2019; Obalade & Muzindutsi, 2019). However, the evidence for the AMH from the non-linear independence perspective is weak. Considering the findings reported in the literature (e.g., Adaramola & Obisesan, 2021; Cruz-Hernández & Mora-Valencia, 2023; Urquhart & McGroarty, 2016), this conclusion justifies additional investigation of the non-linear pattern of the return series of Latin American indices. Likewise, further research should explore the specific factors contributing to the observed changes in informational efficiency in each Latin American market individually, and whether markets' responses to those factors follow the principles of the AMH. Additional studies could also employ other independence tests and address the presence of calendar anomalies from the dynamic viewpoint of the AMH.

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