Market Efficiency, Thin Trading and Non-Linearity in Emerging Markets: Evidence from South Africa

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We examine the change in market efficiency of the South African Stock Exchange JSE FTSE All Share Index following the enhancement of its institutional and regulatory environments and the elimination of major barriers to entry that led to increase in capital flows into the stock market. We provide evidence that the All Share Index is informationally weak-form efficient for the time period of this study. When extending the trading test to include non-linearity for both yearly and five-year periods, we find overall increase in efficiency, particularly in the most recent years in our data. We find significant volatility clustering, implying that the South African market has not consistently compensated for its own risks as measured by time-varying volatility, making the prediction of stock market returns based on previous volatility information difficult.

INTRODUCTION

The pattern of stock price behavior, for both individual stocks and market indexes, has been one of the most studied areas of the capital markets. Most of these studies have focused on developed markets, where data is easily available.

However, the past two decades have witnessed a sharp growth in emerging market economies with a corresponding increase in size and importance. The high growth continues to be fueled by advances in communication and mobile technology that, in turn, continues to revolutionize the way investment decisions are made. While the emerging market spotlight has been on the BRIC nations of Brazil, Russia, India and China, attention is now turning to even much smaller economies such as South Africa, Indonesia, and Mexico, in part, because of the potentially higher returns they offer and because of the desire for diversification.

Governments, regulators, and markets in emerging countries have responded by implementing structural reforms and regulatory mechanisms capable of managing these trends. Invariably, these steps were aimed at improving the efficiency with which their financial markets operate. Easy access to information facilitates investment decisions, management of risk, market discipline, differentiation across economies and market participants. This, in turn, gives appropriate incentives in the conduct of policies, and helps to reduce herding behavior and contagion when market volatility increases (Kahneman 2003). In South Africa, for example, several steps were taken to improve the efficiency of the only national stock exchange – the Johannesburg Stock Exchange (JSE).

The JSE has a long history. The discovery of gold on the Witwatersrand in 1886 led to the birth of many mining and financial companies. The need to raise capital for these companies coupled with the supply of funds from wealthy African investors created the opportunity to open a stock exchange. Thus, the JSE was born on November 8, 1887, having started as the Johannesburg Exchange & Chambers Company a year earlier. Over the years, the exchange underwent significant changes towards modernization.

On June 7, 1996, the open outcry system of trading was modified to an electronic system called TradeElect. In August 1997, the JSE launched a real-time Stock Exchange News Service (Sens) to enhance market transparency and investor confidence. Augmented JSE listing requirements made it obligatory for companies to disseminate any corporate news or price-sensitive information on the service before using any other media outlet. Sens is carried by all the major wire services. The South African government has also licensed Strate Pty. Limited as South Africa's Central Securities Depository (CSD) for the electronic settlement of all financial trades and in September 2000, the exchange moved to its present location in Sandton, Gauteng and changed its official name to the Johannesburg Securities Exchange.

Most significantly, the JSE went into an agreement with the London Stock Exchange (LSE) in 2001 that enabled cross dealing between the two bourses and replaced the JSE's trading system completely with that of the LSE. The JSE also acquired the Bond Exchange of South Africa in 2009 and rebranded it the JSE debt market. Consequently, the JSE added the South African government and corporate bonds as well as interest rate derivatives to its portfolio of traded securities. JSE also became a founding member of the United Nations Sustainable Stock Exchanges initiative on the eve of the United Nations Conference on Sustainable Development (Rio+20).

The JSE's fully automated electronic trading system – the Millennium Exchange – which replaced the JSE TradElect system in 2012, involved moving the trading platform from London to a new platform housed in the JSE building in Johannesburg, thus speeding up the execution of transactions. The JSE also operates an order-driven, central order book trading system with an opening, intra-day and closing auctions.

Despite these steady developments designed to mitigate risk, bring efficiencies to the South African financial markets and improve its profile as an important investment destination on the African continent, the South African Stock Exchange remains small and lacks sufficient market making capacity to ensure the liquidity essential to more stringent requirements of market efficiency. This paper examines the evolving efficiency of the South African Stock Market, following the several transitions, developments and regulations listed above.

Studies examining equity market efficiency are designed to employ tests of the efficient market hypothesis (EMH). EMH tests assume that stock returns are generated by linear processes. In reality, equity returns may exhibit substantial non-linearity due to feedback mechanisms in price movements, market imperfections, and the structure of particular equities markets. In less developed markets, efficiency tests based on linear models may lead to unreliable empirical results. Indeed, researchers have observed non-linearity in both developed and emerging stock markets due to regulatory changes, thin trading, unreliable information, overreaction, high transaction costs, and the effects of inside information (e.g., Koutmos 1992; Sewell et al. 1993 among others). Solibakke (2001) also argued that non-trading effects, as well as non-linear volatility clustering, may contribute significantly to the dynamics of asset pricing in thinly traded emerging stock markets. Thin trading may also induce biases to the moments of return series due to irregular recording intervals, which spawn spurious autocorrelation (Rayhorn et al. 2007).

Trading volumes and trade frequency of South Africa stock market issues are, like in many other developing countries, lower than issues that are trade in more developed markets, leading to less rapid incorporation of new information into prices. To accommodate these data imperfections, we performed only weak-form market efficiency tests for the South African stock market, simultaneously considering non-linearity, thin trading, and structural market changes.

This study is focused on the Johannesburg Stock Market because, like many other emerging markets, the JSE has experienced many structural, institutional and regulatory changes through time. This, in turn, has some impact on both informational and allocational efficiency of the exchange. Following Antoniou and Ergul (1997) and Rayhorn et al. (2007), we examine the evolution of efficiency of the exchange rather than a snapshot of the market at any point in time. This will enable us to identify the impact of any regulatory changes in the efficient functioning of the exchange.

The rest of this paper is organized as follows: Section II presents selected prior research on market efficiency and anomalies in both developed and emerging markets and in particular, African markets. Section III describes the data and methodology employed. Section IV presents and describes the empirical results. Section V provides a brief conclusion and discussion of the results.

PRIOR RESEARCH

The earliest studies of market efficiency in developed markets focused on the weak form of market efficiency that utilized serial correlation of prices over time. Some of these tests were spurred by the random walk theory of price movements, which contended that price changes over time followed a random walk. Alexander (1964), Cootner (1962) and Fama (1965) all report weak serial correlation in stock prices in U.S. stocks. Fama, for instance, finds that 8 of the 30 stocks listed in the Dow had negative serial correlations and that most of the serial correlations were less than 0.05. In other markets, Jennergren and Korsvold (1974) report low serial correlations for the Swedish equity market and Cootner (1962) finds small serial correlations in commodity markets as well. These findings lend support to the weak form of the efficient market hypothesis.

On the other hand, Conrad and Kaul (1988) and Lo and MacKinlay (1988) examine weekly returns and find positive serial correlation over a short horizon. Roll (1984) provides proof of positive serial correlation and contends that such correlation in short period returns is affected by market liquidity and the presence of a bid-ask spread. When stocks are thinly traded, the resulting price changes can create a positive correlation while the presence of bid-ask spread may induce a negative correlation.

While most of the earlier studies of price behavior focused on shorter return intervals, more attention has been paid to price movements over longer periods (one-year to five-year) in recent years. These have resulted in notion of market inefficiencies, commonly called anomalies in the finance literature

Studies on emerging markets of Central Europe and South America have also produced mixed results. Filer and Hanousek (1996) and Dockery and Vergari ((1997) fail to reject the random walk hypothesis in Czech Republic, Hungary, Poland and Slovakia, while Smith and Ryoo (2003) and Gilmore and McManus (2003) reject the random walk behavior in the same markets. Antouniou and Ergul (1997) report market inefficiency from the Istanbul Stock Exchange and attribute this to delays in transaction posting, high transaction costs, thin trading and illiquidity while Panas (1990) fail to reject market efficiency in the Greek market. Urrutia (1995) rejects the random walk for the Argentina, Brazil, Chile and Mexico markets while Ojah and Karemera (1999) find that the random walk holds in the same markets.

Studies on African markets are much less abundant that those of the other emerging markets; and of those that exist, most of the empirical research is focused on the South African Stock Exchange for obvious reasons – the JSE is the oldest and the most advanced on the continent and is likely to generate more data than the other African markets. Dickenson and Muragu (1994), and Olowe (1999) provide results of weak-form market efficiency on the Nairobi and Nigerian Stock Exchanges; Bundoo (2000) reports significant positive first-order correlation in the Mauritius Exchange; Mecagni and Sourial ((1999) report significant departure from weak-form efficiency on the Egyptian stock Exchange; Mollah (2007) rejects the weak-form efficiency in the Botswana Stock Exchange; Simons and Laryea (2006) and Appiah-Kusi and Menya (2003) find weak-form efficiencies on the markets of Ghana, Cote D'Ivoire, Mauritius, South Africa and Zimbabwe while Magnusson and Wydick (2002), Smith (2008) and Al Khazali et al (2007) reject weak for efficiencies in the Ghana, Kenya, Mauritius, Nigeria, South Africa and Zimbabwe stock markets.

This lack of consensus among researchers on the behavior of price patterns on the various markets could be explained by the different methodologies and different data periods used in their studies. At the same it makes way for additional studies to provide more insight into these developing markets.

DATA AND METHODOLOGY

Daily and monthly closing prices of the JSE FTSE All Share Index, from July 1995 to December 2015. Rt was calculated using the first log difference for daily price index.

$$R_t = \ln(P_t/P_{t-1}) \tag{1}$$

where Pt and Pt - 1 represent the current and the previous daily market price index. The FTSE/JSE Africa All Shares Index is a market capitalization-weighted index. Companies included in this index make up the top 99% of the total pre free-float market capitalization of all listed companies on the Johannesburg Stock Exchange.

Correcting for Thin Trading and Non-linearity of Stock Prices

To investigate the efficiency of the JSE FTSE All Share Index, we explicitly consider factors that have been shown to be influential in studies of other emerging markets. To account for possible non-linearity in the All Shares index returns we employ a logistic map equation that addresses the non-linear behavior but does not require specification of the exact nature of the non-linearity:

$$R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 R_{t-1}^2 + \alpha_3 \alpha_2 R_{t-1}^3 + \xi_t \tag{2}$$

where Rt is the index return at time t. If a market is to be deemed to be informationally efficient, all of the coefficients estimated for Equation (2) should be statistically indistinguishable from zero ($\alpha_0 = \alpha_1 = \alpha_2 = \alpha_3 = 0$) and the residual terms, x_t, should follow a white-noise process.

We also adapt the methodology of Miller et al. (1994) to correct for thin trading. To address the thin trading effect, we first posit a moving average model (MA) with sufficient terms to reflect the number of non-trading days and anticipate adjusting the raw returns accordingly. Given the difficulties in identifying the appropriate number of non-trading days, however, Miller et al. proposed an equivalent first-order autoregressive model AR(1) from which an appropriate thin-trading adjustment could be estimated. We follow their parsimonious specification and adopt this AR (1) transformation:

$$R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t \tag{3}$$

Using the residuals from Equation (2), the adjusted return is estimated as:

$$R_t^{adj} = \frac{\varepsilon_t}{1-\alpha_1} \tag{4}$$

where R_t^{adj} is the return at time t adjusted for thin trading. Miller et al. found that this thin trading adjustment reduced the undesirable negative correlations among successive return observations. The model above assumes that the appropriate adjustment for non-trading is constant over time. This assumption may be correct for highly liquid markets, but it is not likely adequate for emerging stock markets undergoing structural changes. Indeed, it is likely inadequate for our study of South Africa's stock market. Therefore, Equation (3) will be estimated recursively. In testing for efficiency, Equation (2) is estimated using corrected returns calculated recursively from Equation (4). Moreover, efficiency will be examined using both linear and non-linear models to gaugethe impact of model refinement on the results. We also examine the JSE FTSE All Share Index to assess structural changes over time. Hence, the models estimated on an annual basis using daily NZSE-40 capital index prices and returns.

Addressing Volatility Clustering and the Effects of Leveraging

We also examined the possible effects of volatility clustering and leverage in the South African stock market returns data. GARCH-M and EGARCH-M models are appropriate for this examination. This class of models allows the simultaneous estimation of both central tendency and volatility parameters in returns data. If the FTSE All Share Index were efficient, the price index returns would not be predictable based on their past volatilities or return levels. Accordingly, after adjusting returns for thin trading across several sub-periods, we estimate the GARCH models and interpret their market efficiency parameter estimates. We also explicitly include time-varying volatility, h_t, in the mean equations for the GARCH and EGARCH models to investigate whether the JSE FTSE All Share Index has compensated over time for its risks as measured by conditional volatility.

The mean and variance equations of the GARCH-M (1, 1) model are specified as:

$$R_t^{adj} = \mu_1 + \mu_2 R_{t-1}^{adj} + \mu_3 \left(R_{t-1}^{adj}\right)^2 + \mu_4 \left(R_{t-1}^{adj}\right)^3 + \delta_1 h_t + \varepsilon_t$$
$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \quad (5)$$

where δ_1 is the risk premium, and ε_t is assumed to be normally distributed with zero mean and conditional variance $h_t = \sigma^2$. Similarly, for corrected returns, we estimate the following EGARCH-M (1, 1) model to capture asymmetric leverage effects between the JSE FTSE All Share Index returns and their conditional volatility:

$$R_t^{adj} = \mu_1 + \mu_2 R_{t-1}^{adj} + \mu_3 \left(R_{t-1}^{adj}\right)^2 + \delta_1 h_t + \varepsilon_t$$
$$log h_t = \alpha_0 + \alpha_1 \frac{|\varepsilon_{t-1}|}{h_{t-1}} + \gamma_1 \frac{\varepsilon_{t-1}}{h_{t-1}} + \beta_1 log h_{t-1} \quad (6)$$

where δ_1 is the risk premium and g1 is a leverage coefficient. The models are estimated for the index using the Berndt et al. (1974) maximum likelihood method (BHHH). In our EGARCH-M (1, 1) framework, if $\gamma_1 \neq 0$, we can conclude that there exist asymmetric effects on conditional volatility. Weak-form efficiency requires that all information about past returns has been fully reflected in current returns, implying that $u_j = 0$ for ∀j. Thus, our attention is focused on the estimates of u_j when testing the lowest hurdle of weak-form EMH. The coefficients (α_1 and β_1) of the conditional volatility equations are crucial when assessing higher hurdle weak-form efficiency.

Testing Weak-form Market Efficiency of the JSE FTSE All Share Index

Our first test of efficiency of the JSE FTSE All Share Index is a serial correlation test. One of the most direct and intuitive tests of the random walk hypothesis (RWH) for an individual time series is to check for serial correlation between two observations of the same series at different dates. Under the weakest version of the random walk, the increments or first-differences of the level of the random walk are uncorrelated at all leads and lags. Therefore, we may test the weak form of efficiency by testing the null hypothesis that the autocorrelation coefficients of the first differences at various lags are not statistically different from zero.

Our second test is to gauge the possible presence of non-linearity in the JSE FTSE All Share Index returns. Equation (2) will be estimated over several sub-periods to affect this test, and the consistency of the estimates over time will be assessed.

Third, after adjusting for thin trading by the methods of Miller et al. (1994) and Antoniou and Ergul (1997), Equations (2) and (3) will be re-estimated. Fourth, to trace the development of efficiency of the market over time, the procedures will be applied to each annual data set. If the South African market is efficient, we expect α_0 and α_1 (the coefficients of the lagged index return and non-linear terms) in Equation (2) not to be significantly different from zero. Both the Ordinary Least Square (OLS) and the Generalized Method of Moment (GMM) techniques are used to estimate the coefficient parameters. Among the OLS assumptions is the requirement that error terms are cross-sectionally uncorrelated and homoscedastic. Because we expect that the error terms may indeed be heteroskedastic the OLS approach has a potential specification error. The GMM framework, on the other hand, can be used to derive homoscedastic- consistent standard errors. Furthermore, the GMM technique is helpful when error terms deviate from normality and serial independence. Coefficients estimated with each technique are reported and assessed.

TABLE 1
RANDOM WALK TEST ON A FIVE-YEAR BASIS WITHOUT NON-LINEARITIES FOR CAPITAL INDEX RETURNS

Sub-Periods	α_0	α_1	Ljung-Box Q
Panel A: The linear model for uncorrected index returns			
1. 1996 - 2000	0.026	0.136	116.272
	(0.721)	(4.839)	
2. 2001 - 2005	0.058	0.089	93.176
	(1.861)	(3.168)	
3. 2006 - 2010	0.045	0.023	83.038
	(1.017)	(0.811)	
4. 2011 - 2015	0.042	-0.028	75.352
	(1.56)	(-0.981)	
Panel B: The linear model for corrected index returns to adjust for thin trading			
1. 1996 - 2000	0	-0.009	82.678
	(-0.008)	(-0.304)	
2. 2001 - 2005	0	-0.002	79.291
	(0.01)	(-0.085)	
3. 2006 - 2010	-0.001	0.001	79.346
	(-0.025)	(0.019)	
4. 2011 - 2015	0	-0.002	75.545
	(-0.016)	(-0.075)	

The t-statistics are reported in parenthesis. The results of Ljung-Box Q test statistics for the residuals up to 52 lags are reported in the last column.

EMPIRICAL RESULTS

Panel A of Table 1 reports the coefficient estimates of the linear model in Equation (3) for uncorrected capital index returns using both the OLS and GMM techniques for four five−year sub-periods. From the coefficient of lagged returns (α_1) using the uncorrected index returns, we can reject the null hypothesis of market efficiency at any conventional significance level for the periods 1996-2000 and 2001-2005. However, we cannot reject the null hypothesis for the years 2006-2010 and 2011-2015. One might conclude that the JSE FTSE All Share Index was informationally inefficient (weak form) during the first ten years of our study, but became weak-form efficient after 2005. If true, a possible explanation would be the modernization of the South African stock exchange and South Africa itself. However, the Ljung and Box Q-test reported in Panel A of Table 1 show the serial correlation between the returns and the lagged returns for up to 52 lags are statistically significant. This serial correlation implies that the JSE FTSE All Share Index was informationally weak-form inefficient for the time period of this study.

TABLE 2-A
RANDOM WALK TEST ON A YEARLY BASIS WITHOUT NON-LINEARITIES FOR CAPITAL INDEX RETURNS

Year	α_0	α_1
1996	0.024	0.115
	(0.505)	(1.833)
1997	-0.036	-0.062
	(-0.435)	(-0.978)
1998	-0.029	0.222
	(-0.26)	(3.58)
1999	0.168	0.182
	(2.592)	(2.914)
2000	-0.01	0.139
	(-0.12)	(2.194)
2001	0.09	0.093
	(1.027)	(1.47)
2002	-0.043	0.095
	(-0.578)	(1.509)
2003	0.038	0.169
	(0.548)	(2.706)
2004	0.077	0.019
	(1.34)	(0.302)
2005	0.145	-0.018
	(2.71)	(-0.291)

The t-statistics are reported in parenthesis.

Thin trading has been a defining characteristic of smaller bourses including the JSE. Studies show the potential to draw erroneous conclusions if the phenomenon is not taken into account. We adjusted the data for thin trading effects using the linear model (Equations 3 and 4) and report these results in Panel B of Table 1. For all four five-year periods, the coefficients are not statistically significant, lending support for the thin trading hypothesis. However, the Ljung and Box Q statistics still suggest the index was not informationally weak-form efficient.

Table 2-a shows the year by year evolution vs. the five-year results from Table 1 panel A. All of the coefficients become insignificant after 2005. Drawing any conclusions from these results would be premature. Tale 2-b adjusts for the possibility of thin trading. None of the coefficients are significant for any year.

Tables 1 and 2 seem to agree with one another and ignoring the Ljung-Box Q statistics one could conclude that the South African market has become more weak-form efficient.

To allow for possible non-linearity in the return generating process that might affect the efficiency of the JSE FTSE All Share Index, we also incorporated lagged and non-linear terms into the model. Panel A of Table 3 shows the estimation results obtained when the non-linear model in Equation (2) was applied.

TABLE 2-A (CONTINUED)

Year	α_0	α_1
2006	0.136	-0.051
	(1.528)	(-0.807)
2007	0.06	0.009
	(0.779)	(0.135)
2008	-0.114	0.031
	(-0.789)	(0.495)
2009	0.093	0.08
	(0.949)	(1.265)
2010	0.061	-0.026
	(0.907)	(-0.413)
2011	-0.002	0.045
	(-0.021)	(0.712)
2012	0.088	-0.078
	(1.933)	(-1.224)
2013	0.068	-0.035
	(1.153)	(-0.552)
2014	0.031	-0.057
	(0.606)	(-0.899)
2015	0.033	-0.089
	(0.454)	(-1.289)

The t-statistics are reported in parenthesis.

TABLE 2-B
RANDOM WALK TEST ON A YEARLY BASIS WITHOUT NON-LINEARITIES FOR ADJUSTED CAPITAL INDEX RETURNS

Year	α_0	α_1
1996	0.002	0.003
	(0.03)	(0.042)
1997	0.001	-0.012
	(0.004)	(-0.181)
1998	0.003	-0.011
	(0.041)	(-0.177)
1999	0.001	-0.01
	(0.012)	(-0.159)
2000	0.002	-0.003
	(0.019)	(-0.047)
2001	-0.009	-0.004
	(-0.106)	(-0.062)
2002	0	0
	(0)	(0.004)
2003	-0.005	-0.002
	(-0.077)	(-0.03)
2004	-0.003	0.001
	(-0.065)	(0.016)

The t-statistics are reported in parenthesis.

TABLE 2-B (CONTINUED)

Year	α_0	α_1
2005	-0.005	0.001
	(-0.058)	(0.012)
2006	-0.004	0.001
	(-0.048)	(0.011)
2007	-0.005	0.003
	(-0.036)	(0.046)
2008	-0.004	0.002
	(-0.042)	(0.033)
2009	-0.003	-0.002
	(-0.046)	(-0.035)
2010	-0.003	0.004
	(-0.032)	(0.064)
2011	-0.009	-0.011
	(-0.209)	(-0.17)
2012	-0.008	0.001
	(-0.135)	(0.022)
2013	-0.003	-0.005
	(-0.055)	(-0.08)
2014	0.002	-0.008
	(0.036)	(-0.11)
2015	0.002	0.003
	(0.03)	(0.042)

The t-statistics are reported in parenthesis.

Panel B of Table 3 reports estimation results when we adjust for thin trading and include non-linearity in the model.

TABLE 3
RANDOM WALK TEST ON A FIVE-YEAR BASIS WITH NON-LINEARITIES FOR CAPITAL INDEX RETURNS

Sub-Periods	α_0	α_1	α_2	α_3
Panel A: The linear model for uncorrected index returns				
1. 1996 - 2000	0.026	0.269	-0.012	-0.006
	(0.682)	(8.369)	(-1.337)	(-6.23)
2. 2001 - 2005	0.087	0.102	-0.024	-0.001
	(2.497)	(2.841)	(-1.864)	(-0.349)
3. 2006 - 2010	0.01	0.024	0.014	0
	(0.203)	(0.622)	(1.686)	(0.038)
4. 2011 - 2015	0.005	0.027	0.039	-0.013
	(0.156)	(0.642)	(2.352)	(-1.679)

The t-statistics are reported in parenthesis.

For both panels, only the 2006-2010 lustra had insignificant coefficients. This suggests that the return generating process was both non-linear and dependent on past values in all but one five-year period. However, Tables 4-a and 4-b tell a slightly different story.

TABLE 3 (CONTINUED)

Sub-Periods	α_0	α_1	α_2	α_3
Panel B: The linear model for corrected index returns to adjust for thin trading				
1. 1996 - 2000	-0.013	0.126	0	-0.004
	(-0.306)	(3.81)	(-0.025)	(-6.413)
2. 2001 - 2005	0.034	0.001	-0.023	0
	(0.883)	(0.019)	(-1.983)	(-0.021)
3. 2006 - 2010	-0.037	0.003	0.014	0
	(-0.736)	(0.075)	(1.672)	(0.044)
4. 2011 - 2015	-0.034	0.055	0.037	-0.013
	(-1.142)	(1.306)	(2.213)	(-1.62)

The t-statistics are reported in parenthesis.

To investigate the evolution of market efficiency in South Africa over time, we estimated Equations (2) and (3) on annual subsets of the index data. The results appear in Tables 4-a. Some of the coefficients of lagged returns are significantly different from zero, but none are after 2006.

TABLE 4-A
RANDOM WALK TEST ON A YEARLY BASIS WITH NON-LINEARITIES FOR CAPITAL INDEX RETURNS

Year	α_0	α_1	α_2	α_3
1996	-0.041	0.252	0.101	-0.054
	(-0.74)	(2.698)	(2.084)	(-1.784)
1997	-0.021	0.354	-0.038	-0.008
	(-0.263)	(4.033)	(-2.744)	(-5.711)
1998	-0.013	0.328	-0.014	-0.008
	(-0.104)	(3.627)	(-0.612)	(-1.568)
1999	0.129	0.208	0.038	-0.008
	(1.817)	(2.552)	(1.272)	(-0.921)
2000	-0.057	0.312	0.015	-0.011
	(-0.616)	(4.027)	(0.498)	(-2.173)
2001	0.095	0.104	-0.003	-0.001
	(0.987)	(1.151)	(-0.14)	(-0.16)
2002	0.015	0.11	-0.041	-0.003
	(0.168)	(1.165)	(-1.139)	(-0.18)
2003	0.173	0.247	-0.107	-0.015
	(2.011)	(2.403)	(-2.551)	(-0.619)
2004	0.084	0.084	-0.008	-0.017
	(1.273)	(0.96)	(-0.207)	(-1.012)
2005	0.198	0.06	-0.083	-0.032
	(3.071)	(0.612)	(-1.632)	(-0.961)

The t-statistics are reported in parenthesis.

We cannot say that the market was efficient for all of the years of the study but it appears the case for efficiency strengthened. The puzzling thing about Table 4-a is the data seem at odds with the results from Table 3 Panel A. Table 3 Panel A doesn't give the impression for efficiency while Table 4-a shows marked improvement over time.

Table 4-b goes one step farther and also includes Equation (4) for the yearly estimates. Unlike in Table 3 panel B, Table 4-b supports the inference that for most years the market is weak-form efficient.

TABLE 4-A (CONTINUED)

Year	α_0	α_1	α_2	α_3
2006	0.066	0.122	0.019	-0.014
	(0.683)	(1.401)	(0.895)	(-2.547)
2007	0.072	0.177	-0.029	-0.032
	(0.803)	(1.83)	(-0.864)	(-2.373)
2008	-0.21	-0.052	0.017	0.004
	(-1.249)	(-0.509)	(1.067)	(1.074)
2009	0.063	0.067	0.013	0.001
	(0.519)	(0.687)	(0.402)	(0.098)
2010	0.004	0.092	0.046	-0.024
	(0.048)	(1.009)	(1.413)	(-1.799)
2011	-0.061	0.091	0.043	-0.009
	(-0.683)	(0.875)	(1.218)	(-0.541)
2012	0.046	-0.019	0.074	-0.033
	(0.846)	(-0.199)	(1.288)	(-0.807)
2013	0.046	-0.076	0.033	0.016
	(0.653)	(-0.7)	(0.636)	(0.543)
2014	-0.006	-0.023	0.064	-0.016
	(-0.104)	(-0.274)	(1.226)	(-0.881)
2015	-0.024	0.165	0.024	-0.054
	(-0.295)	(1.5)	(0.584)	(-2.68)

The t-statistics are reported in parenthesis.

TABLE 4-B
RANDOM WALK TEST ON A YEARLY BASIS WITH NON-LINEARITIES FOR CORRECTED CAPITAL INDEX RETURNS

Year	α_0	α_1	α_2	α_3
1996	-0.071	0.135	0.087	-0.041
	(-1.132)	(1.441)	(2.006)	(-1.73)
1997	0.013	0.425	-0.055	-0.01
	(0.174)	(4.931)	(-3.186)	(-5.816)
1998	-0.028	0.058	0.002	-0.003
	(-0.171)	(0.631)	(0.123)	(-0.891)
1999	-0.038	0.024	0.028	-0.005
	(-0.438)	(0.295)	(1.156)	(-0.827)
2000	-0.079	0.154	0.028	-0.008
	(-0.771)	(1.92)	(1.365)	(-2.298)
2001	0.013	-0.011	-0.005	0.001
	(0.125)	(-0.124)	(-0.275)	(0.146)
2002	0.061	0.012	-0.041	-0.001
	(0.61)	(0.13)	(-1.194)	(-0.115)
2003	0.14	0.054	-0.079	-0.009
	(1.351)	(0.522)	(-2.24)	(-0.518)
2004	0.006	0.06	-0.01	-0.016
	(0.088)	(0.679)	(-0.271)	(-0.984)
2005	0.058	0.058	-0.099	-0.036
	(0.917)	(0.59)	(-1.808)	(-1.01)

TABLE 4-B (CONTINUED)

Year	α_0	α_1	α_2	α_3
2006	-0.051	0.174	0.014	-0.014
	(-0.554)	(2.024)	(0.586)	(-2.429)
2007	0.017	0.167	-0.034	-0.032
	(0.186)	(1.737)	(-0.977)	(-2.389)
2008	-0.092	-0.082	0.015	0.004
	(-0.531)	(-0.804)	(0.97)	(1.05)
2009	-0.042	-0.01	0.013	0.001
	(-0.321)	(-0.104)	(0.47)	(0.119)
2010	-0.05	0.123	0.04	-0.026
	(-0.666)	(1.324)	(1.2)	(-1.773)
2011	-0.066	0.051	0.042	-0.009
	(-0.705)	(0.493)	(1.24)	(-0.579)
2012	-0.045	0.053	0.076	-0.033
	(-0.91)	(0.561)	(1.23)	(-0.699)
2013	-0.033	-0.039	0.041	0.019
	(-0.473)	(-0.376)	(0.703)	(0.613)
2014	-0.037	0.032	0.065	-0.017
	(-0.656)	(0.374)	(1.223)	(-0.864)
2015	-0.042	0.25	0.018	-0.065
	(-0.561)	(2.295)	(0.385)	(-2.725)

The t-statistics are reported in parenthesis.

Finally, Tables 5 and 6 report estimation results obtained by maximum likelihood estimation (MLE) when GARCH-M (1, 1) and EGARCH-M (1, 1) models were applied to the thin trading adjusted returns data. All of the estimation results show that there is significant volatility clustering in the JSE FTSE All Share Index evidenced by significant parameter values of β_1 across various sub-periods. Also, Table 6 reveals definite signs of leverage effects between the JSE FTSE All Share Index returns and conditional volatility of the JSE FTSE All Share Index. It appears that the South African market has not consistently compensated for its own risks as measured by time-varying volatility. Therefore, it may be difficult to predict stock market returns based on previous volatility because the index returns do not appear to provide investors with a risk premium measured by past conditional volatility.

TABLE 5
PARAMETER ESTIMATES OF GARCH-M (1, 1) MODEL WITH NON-LINEARITIES

Period	μ_1	μ_2	μ_3	μ_4	δ_1	α_0	α_1	β_1
Panel A: raw capital index returns								
1. 1996 - 2000	0.038	0.218	0.006	-0.004	0.005	0.020	0.119	0.878
	(0.900)	(5.440)	(0.260)	(-1.040)	(0.110)	(4.300)	(10.710)	(109.080)
2. 2001 - 2005	0.014	0.122	-0.061	-0.005	0.064	0.025	0.089	0.892
	(0.230)	(3.130)	(-3.180)	(-0.940)	(1.000)	(2.370)	(6.270)	(52.030)
3. 2006 - 2010	0.072	0.037	0.003	-0.002	0.007	0.034	0.118	0.868
	(1.400)	(0.980)	(0.160)	(-0.600)	(0.210)	(2.520)	(6.000)	(40.080)
4. 2011 - 2015	-0.022	0.020	0.026	-0.014	0.041	0.016	0.067	0.915
	(-0.410)	(0.470)	(0.840)	(-1.040)	(0.580)	(2.900)	(5.070)	(54.870)
5. 1996 - 2015	0.046	0.090	-0.006	-0.004	0.017	0.018	0.103	0.889
	(2.220)	(4.920)	(-0.620)	(-1.890)	(0.810)	(7.3)	(17.88)	(170.62)

The t-statistics are reported in parenthesis.

TABLE 5 (CONTINUED)

Period	μ_1	μ_2	μ_3	μ_4	δ_1	α_0	α_1	β_1
Panel B: Adjusted capital index returns								
1. 1996 - 2000	0.014	0.073	0.008	-0.003	0.005	0.028	0.122	0.875
	(0.290)	(1.780)	(0.390)	(-1.060)	(0.130)	(4.320)	(10.570)	(103.680)
2. 2001 - 2005	-0.047	0.020	-0.055	-0.003	0.058	0.031	0.089	0.891
	(-0.690)	(0.500)	(-3.020)	(-0.680)	(0.990)	(2.380)	(6.320)	(51.650)
3. 2006 - 2010	0.029	0.015	0.003	-0.002	0.006	0.036	0.118	0.868
	(0.550)	(0.410)	(0.170)	(-0.600)	(0.190)	(2.510)	(6.000)	(40.130)
4. 2011 - 2015	-0.061	0.048	0.024	-0.015	0.043	0.015	0.067	0.915
	(-1.160)	(1.090)	(0.730)	(-1.010)	(0.590)	(2.910)	(5.080)	(54.940)
5. 1996 - 2015	0.003	0.030	-0.006	-0.004	0.016	0.021	0.103	0.889
	(0.140	(1.650	(-0.560)	(-1.910)	(0.810)	(7.310)	(17.880)	(170.450)

The t-statistics are reported in parenthesis.

TABLE 6
PARAMETER ESTIMATES OF EGARCH-M (1,1) MODEL WITH NON-LINEARITIES

Period	μ_1	μ_2	μ_3	δ_1	α_0	α_1	γ_1	β_1
Panel A: raw capital index returns								
1. 1996 - 2000	0.042	0.178	0.031	-0.016	0.018	-0.091	0.276	0.959
	(0.960)	(5.220)	(2.260)	(-0.360)	(3.920)	(-7.180)	(12.770)	(114.710)
2. 2001 - 2005	0.028	0.090	-0.055	0.041	0.002	-0.066	0.161	0.978
	(0.490)	(3.000)	(-3.360)	(0.680)	(0.480)	(-5.390)	(7.290)	(104.060)
3. 2006 - 2010	0.000	0.023	0.000	0.015	0.010	-0.117	0.113	0.977
	(0.000)	(0.780)	(0.020)	(0.490)	(2.220)	(-6.820)	(4.100)	(156.210)
4. 2011 - 2015	-0.069	0.008	0.036	0.049	-0.011	-0.148	0.033	0.966
	(-1.590)	(0.250)	(1.510)	(0.800)	(-2.210)	(-9.930)	(1.920)	(110.420)
5. 1996 - 2015	0.027	0.070	-0.004	0.012	0.006	-0.083	0.190	0.977
	(1.360)	(4.840)	(-0.550)	(0.610)	(3.230)	(-15.490)	(22.270)	(326.180)
Panel B: Adjusted capital index returns								
1. 1996 - 2000	0.017	0.034	0.025	-0.010	0.030	-0.091	0.282	0.958
	(0.330)	(0.980)	(1.930)	(-0.260)	(5.520)	(-7.150)	(12.780)	(111.490)
2. 2001 - 2005	-0.034	-0.007	-0.049	0.036	0.006	-0.065	0.161	0.978
	(-0.560)	(-0.220)	(-3.160)	(0.670)	(1.390)	(-5.390)	(7.310)	(103.810)
3. 2006 - 2010	-0.047	0.002	0.001	0.014	0.011	-0.118	0.111	0.977
	(-0.910)	(0.050)	(0.040)	(0.480)	(2.350)	(-6.760)	(4.060)	(156.470)
4. 2011 - 2015	-0.106	0.037	0.038	0.049	-0.013	-0.148	0.033	0.966
	(-2.520)	(1.180)	(1.520)	(0.790)	(-2.440)	(-9.910)	(1.940)	(110.870)
5. 1996 - 2015	-0.018	0.010	-0.004	0.012	0.009	-0.083	0.190	0.977
	(-0.870)	(0.690)	(-0.660)	(0.650)	(4.670)	(-15.480)	(22.220)	(325.470)

The t-statistics are reported in parenthesis.

It is interesting to note that with either GARCH model there is little difference in the results between adjusted and raw returns.

CONCLUSIONS

In this paper, we examined the market efficiency of the JSE FTSE All Share Index considering characteristics such as thin trading and non-linearity, which are prominent in most of emerging markets. As the JSE FTSE All Share Index has evolved over time, its institutional and regulatory environments have been enhanced, and barriers to entry have been eliminated. The result has been increased efficiency and a resultant increase in capital flows (IMF report).

Our short-term information test with only one lagged return shows that the JSE FTSE All Share Index returns were, to a degree, predictable based on previous returns for the periods 1996-2000 and 2001-2005. However, there is no empirical evidence of price dependence and predictability in the JSE FTSE All Share Index during more recent periods 2006-2010 and 2010-2015. We also find support for the thin trading hypothesis. For our 52-lags long-term information test, we find consistent evidence that the JSE FTSE All Share Index was informationally weak-form inefficient for the time period of this study. When extending the trading test to include non-linearity both yearly or for each five-year period, we find that overall the efficiency gradually strengthened for the JSE although for most years the market is weak-form efficient.

Our GARCH and EGARCH tests report significant volatility clustering, implying that the South African market has not consistently compensated for its own risks as measured by time-varying volatility, making the prediction of stock market returns based on previous volatility information difficult.

The implication is that the JSE FTSE All Share Index has become more efficient in most recent years and this improvement can be attributed to regulatory changes and modernization efforts.

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