# Share price reaction to earnings announcement on the JSE-ALtX: A test for market efficiency

V.F. Mlonzi, J. Kruger & M.G. Nthoesane

## ABSTRACT

Management has a duty to inform both shareholders and investors about the state of health of a firm. Earnings announcements provide a yardstick that can be utilised by the market to assess the wealth and profitability of a firm. The purpose of the study was to investigate whether there are any significant abnormal returns around the public announcement of earnings and to establish whether the efficient capital market hypothesis applies to the small ALtX market.

The study focused on all the companies listed on the JSE-ALtX that announced annual earnings between 1 January and 31 December 2009. The method used for calculating the expected returns was the Capital Asset Pricing Model (CAPM).

Empirical evidence demonstrates that there is substantial negative share price reaction to earnings announcements on the small ALtX stock market. The ALtX also shows the weak form of market efficiency. The study concluded that during a recessionary period, shareholders' wealth is eroded in the small ALtX market; however, the weak form of market efficiency provides an opportunity for entrepreneurs and investors to exploit the market for profits when the market is performing well.

**Key words:** efficient market hypothesis, earnings announcement, capital asset pricing model, post-earnings announcement drift, event studies

---

Ms V.F. Mlonzi is at the Graduate School of Business Leadership, University of South Africa (Unisa); Dr J. Kruger is a Senior Lecturer at the Unisa Graduate School of Business Leadership; Mr M.G. Nthoesane is Corporate Services Manager, Centre for Business Management, Unisa. E-mail: info.lumengo@yahoo.com; nthoemg@unisa.ac.za

## Introduction

Efficient Market Hypothesis theory has stimulated a new dimension of studies in behavioural finance in the last three decades. More importantly, it has emerged as the "cornerstone of modern-day finance theory, dominating the mainstream of finance research" (Hussin, Ahmed & Ying 2010: 36). Fama, Fisher, Jensen and Roll (1969) argued that there are three forms of market efficiency, namely, the weak form, the semi-strong form and the strong form. Accordingly, many empirical studies have been conducted to test the validity of the market efficiency concept. One of the ways of testing this concept has been the observation of stock market reaction to corporate announcements.

Capital markets react to various corporate announcements, and one such significant announcement is the earnings announcement. In an efficient market, if the announcement conveys vital information, then it is assumed that such information will be reflected by stock price movements (Hussin et al. 2010) as soon as the information is publicly released to the market. Earnings, per se, are an interesting phenomenon to observe, because they carry inside information about the company's future prospects (Aharony & Swary 1980). The literature argues that earnings announcements are one of the important signalling devices used by managers to transmit information to the public about the firm's future prospects (Lonie, Abeyratna, Power & Sinclair 1996). Earnings announcements are thus one of the critical components of testing market efficiency. Management further uses earnings information to inform both shareholders and investors about the state of health of a firm. In other words, earnings announcements provide a yardstick that can be utilised by the market to assess the wealth and profitability of a firm. If the market is efficient, then any new information released is instantaneously reflected in the share price. Therefore, as earnings are publicly announced, the share price should immediately reflect this announcement and therefore deny investors any above-average risk-adjusted profits.

Interestingly, many studies have been conducted on the effect of earnings announcements on market reactions, but the findings are contradictory. For example, Cready and Gurun (2010) found that lower earnings results exhibit positive cumulative average abnormal returns (CAAR) and move market values higher. (Ball and Shivakumar (2008) report that earnings announcements provide a modest but not overwhelming amount of information in relation to the market, while Hussin et al. (2010) found that lower earnings lead to negative market reaction. Furthermore, these studies are silent on the state of the business cycle when the studies were conducted. This article is based on research conducted during a recession. During a recessionary period of the business cycle, business and economic activity are usually

low (Johnson 1999), hence it is felt that it will be important to assess the information nature of earnings announcements by observing the share price movement around the public announcement of earnings.

The aim of this study was to investigate the behaviour of investors during tough economic times by observing the share price movement on the JSE ALtX on earnings announcements. This research was further intended to establish the information content of earnings announcements during a recessionary period of the business cycle and to shed light on the efficiency of the small JSE ALTX market exchange.

## Earnings announcements

Company earnings have been the subject of research for decades, and different angles have been explored to define the importance of company earnings. Aharony and Swary (1980) argue that company managers use earnings as a signalling tool to convey information about the prospects of a company, and they also argue that like dividends, if earnings convey useful information, this will be reflected in stock price changes immediately following a public announcement. Black (1980) adds to this by highlighting that users of financial statements expect earnings to be a measure of value, rather than a change in value.

Earnings provide critical information to shareholders as far as the company's past performance is concerned, and are also used extensively in forecasting future performance and valuations of equity. The primary role of reported earnings is to provide some predictive information about future earnings, and this information should at least be useful for both present and potential investors in making rational investment decisions regarding the company. For this reason, Barker and Imam (2008) highlight that a company exhibiting high earnings is viewed more favourably by users of financial statements (including investors) than a company with low earnings. Earnings also display management's competitiveness in profitably running a company and the ability to deliver value to shareholders. Hence, a reaction to earnings announcements is regarded as an interesting subject for analysis.

A study by Dey and Radhakrishna (2008) of earnings announcements concludes that institutional investors do not earn excess returns from trading before or after the announcements. To the contrary, the authors found that individual investors do earn significantly weak positive excess returns just hours after the announcements, but they also suffer significantly negative excess returns on the day after the announcement. Louhichi (2008) provides evidence showing that intraday analysis of earnings announcements is more precise than the daily studies. The author contends that price reaction to earnings disclosures begins very quickly, therefore supporting

intraday analysis rather than daily analysis. Accordingly, Bernard and Thomas (1989) support the concept of intraday analysis by highlighting that new information exerts its full influence on the stock price within an hour after announcements. These studies argue that useful earnings information happens within hours, suggesting that daily returns, as opposed to intraday returns, miss out on the usefulness of earnings information.

Other researchers have also found abnormal stock returns after the announcement of quarterly earnings (Kiger 1972; Foster, Olsen & Shevlin 1984; Chatuverdi 2000). Mendenhall (1991) found that stock price reaction to semi-annual earnings announcements yielded abnormal returns during both the pre-announcement and post-announcement dates, but Das, Pattanayak and Pathak (2008) found no evidence of significant abnormal returns around quarterly earnings announcements. Furthermore, the latter highlight that it could not be established that the share price drifts positively in the case of good announcements or negatively in the case of bad announcements, meaning that these announcements carry little information value for investors. Christensen, Smith and Stuerke (2004) present an unusual finding in that, contrary to finance theory that hypothesises that small capitalisation shares yield increased returns, they found that in the insurance industry, quarterly earnings of larger firms and firms with larger analyst following are generally more informative and that there is a more positive association between market reaction and earnings announcements.

Lev (1989) argues that there is only a weak correlation between stock markets and earnings announcements; he claims that less than 10% of market returns around annual earnings announcements can be explained by the information release. Bhana (1995/96) postulates that an asymmetry of response behaviour exists with respect to positive and negative earnings announcements. The author argues that unfavourable announcements attract more attention in the market.

## Post-earnings announcement drift

Post-earnings announcement drift (PEAD) is defined by Ball and Brown (1968), Chordia and Shivakumar (2005), Chordia, Goyal, Sadka, Sadka and Shivakumar (2009), and Livnat and Mendenhall (2006) as the tendency for a stock's cumulative returns to drift in the direction of a recent earnings surprise for several weeks following an earnings announcement. This concept, which is also referred to as standardised unexpected earnings (SUE), means that, after a firm announces earnings that exceed (or fall short of) a proxy for the market's expectation of earnings, subsequent abnormal returns tend to be higher (or lower) than normal for several weeks or even

months (Livnat & Mendenhall 2006). These authors also conclude that the drift is significantly larger when using the analysts' forecasts, and that those investors who view the drift as a violation of market efficiency and hope to exploit it should also use the earnings surprise signal, or combination of signals, that maximises the drift.

Chordia and Shivakumar (2005) hypothesise that part of the drift anomaly is attributable to the inflation illusion (in other words, that firms with positive earnings sensitivities to inflation tend to be undervalued, and vice versa). They argue that investors do not account for the impact of inflation on future earnings growth and do not fully incorporate all macroeconomic-related earnings expectations into price, which could explain the persistence of PEAD.

Chordia et al. (2009) posit that PEAD is prevalent mainly in stocks that are relatively illiquid. Liquidity generally reflects the ability to buy and sell sufficient quantities at low trading costs and without having a significant impact on the market price. The findings conclude that transaction costs will otherwise erode most or all of the gains from trading on annual earnings strategy. This lack of profitability suggests that the "violations of efficiency market hypothesis arising from earnings momentum are not so egregious" (Chordia et al. 2009).

## Earnings announcements around the world

Earnings studies in France by Gajewski and Quéré (2001) found that there is a significant market reaction to both half-year and annual earnings announcements. The authors also conclude that the reaction to annual earnings is stronger than the reaction observed for half-year earnings; however, they argue that the richer information content of annual earnings is not the sole factor explaining the difference, and they allude to the possibility of earnings management. This is in line with the arguments advanced by Putman, Griffin and Kilgore (2008), and Chai and Tung (2002). Gajewski and Quéré (2001) conclude that in France, greater attention and sensitivity are based on annual earnings, and that this disparity is therefore a strong incentive for management to announce bad news strategically in half-year earnings rather than in annual earnings.

Louhichi (2008), conversely, highlight the following regarding intraday trading on the Euronext Paris stock market:

- Investors react positively to good news and negatively to bad announcements.
- Any excess returns upon the announcement of earnings dissipate within 15 minutes.

- Earnings tend to take longer before converging back to equilibrium following bad announcements, and price reversal takes about 30 minutes following bad announcements.
- Earnings release is accompanied by a rise in volume, which lags the price adjustment back to equilibrium.

Chan, Faff and Ramsay (2005) provide Australian evidence concerning earnings announcements. They focused on the size effect of earnings and found that larger firms respond significantly more positively to earnings than do micro-capitalisation, small and medium-sized firms, and this finding corresponds with that of Christensen et al. (2004). They attribute this positive market response to the fact that larger firms could be releasing additional information following the annual earnings announcement. They further note that investors appear to regard earnings accompanied by dividends to be of higher quality.

Cheon, Christensen and Bamber (2001) in America conducted a study comparing the traditional New York Stock Exchange (NYSE) and over-the-counter NASDAQ. They found that NASDAQ firms' earnings announcements significantly exceed the abnormal returns associated with NYSE firms' earnings announcements and attribute this to:

- Differences between NYSE and NASDAQ firms' pre-disclosure information environment
- Differences between NYSE and NASDAQ firms' expected earnings growth
- Differences in investor sensitivity to growth opportunities in NYSE and NASDAQ firms.

This is in conflict with the Australian finding that larger firms respond significantly more positively (Chan et al. 2005).

Kong and Taghavi (2006) provide a Chinese perspective and indicate that the abnormal returns increase markedly (through an overreaction) four days before the announcement, and decrease (through rectification) four to six days after the announcement. This finding was consistent in both the Shanghai and Shenzhen markets.

In India, Das et al. (2008) conducted a study separating 'good' and 'bad' announcements. The authors found no evidence of significant abnormal returns for either of the groups. The study was also not able to establish that the share price drift was positively affected in the case of good announcements, or negatively affected by bad announcements. However, it should be noted that this study focused only on larger firms: there is conjecture that large firms receive greater attention from

market participants and that fundamental information is thus rapidly incorporated into prices, leaving no space for superior returns.

In Greece, Dasilas, Lyroudi & Ginoglou (2008) posit that there is positive market reaction to joint earnings and dividend announcement. However, it should be noted that this result is based on a very small sample of 24 announcements. Due to the small sample size, caution should be exercised with regard to statistical inference. Again, dividends clearly confound the market reaction to earnings announcements.

The British study by Lonie et al. (1996) resembles the Greek study (Dasilas et al. 2008) in the sense that both earnings and dividends announcements were observed; however, the sample was further subdivided into whether earnings and/or dividends increased or declined. It was found that companies with a combination of bad announcements had the largest negative abnormal returns.

Sponholtz (2008), in her study in a small Danish stock market, presented the following evidence related to earnings announcements:

- Abnormal volatility in the days surrounding earnings announcements, which persists several days after the announcement; however, there was no quantification of the duration of this volatility
- Significant positive abnormal returns accompanying the announcements
- The slow adjustment of prices following announcements, indicating market inefficiency in this market.

## Efficient market hypothesis

Many conflicting results are reported around the globe regarding the concept and theory of efficient capital market hypothesis. Many studies around the world seem to conclude that capital markets follow the weak form of efficient market. These studies include Varamini and Kalash (2008); a Turkish study by Ozdemir (2008); a Bahrain study by Asiri (2008); Sharma (2009); a Hong Kong study by Jarrett (2008); Middle East and African studies by Lim (2009); Gulf Cooperation Countries (GCC) by Abedini (2009); Arab markets by Abdmoulah (2010); Asian markets by Lim, Brooks and Hinich (2008), Lim, Brooks and Kim (2008), and Jarrett and Kyper (2006); a French study by Gajewski and Quéré (2001); an Australian study by Christensen et al. (2004); Chan, Lin & Strong, (2005); an American study by Cheon et al. (2001); a Chinese study by Kong and Taghavi (2006); a Greek study by Dasilas et al. (2008); a UK study by Lonie et al. (1996); a Danish study by Sponholtz (2008); and South African studies by Bhana (1995/96, 2005, 2007), Mushidzi and Ward (2004), and Nthoesane (2011). Furthermore, Hung, Lee & Pai (2009) conclude that only large

cap stock indices (but not small cap stock indices) demonstrate a weak form of an efficient market.

Some researchers reach different conclusions with respect to efficiency and inefficiency and conclude that the capital market is inefficient. These studies highlight that it is due to this inefficiency that entrepreneurs are able to spot and exploit market opportunities. These researchers include Lim and Brooks (2009), Stanley and Samuelson (2009), Kim and Shamsuddin (2008), Charles and Darné (2009), Deshmukh, Fatemi and Fooladi (2008), Guidi (2010), Asamoah (2010), Metghalchi, Chang and Marcucci (2008), Zunino, Zanin, Tabak, Pérez and Rosso (2009), and Sappideen (2009).

Finally, some studies do support the strong form of efficient capital markets, in the sense that no above-average abnormal returns were observed. These include Das et al. (2008), Laopodis (2009), Wang and Corbertt (2008), Mittal and Jain (2009), Mallikarjunappa and Manjunatha (2009), Floros and Vougas (2008), Basistha and Kurov (2008), Simpson, Emery and Moreno (2009), Louhichi (2008), Lonie et al. (1996), Sponholtz (2008), Varamini and Kalash (2008), Fama et al. (1969), Laopodis (2003), Grubel (1979), Malkiel (2005) and Laidroo (2008).

## Hypothesis formulation

The purpose of the study was to investigate whether there are any significant abnormal returns (whether positive or negative) related to the public announcement of earnings and to establish whether the efficient capital market hypothesis applies to the small JSE ALtX market.

The null hypothesis states that cumulative average abnormal returns (CAAR) due to earnings announcements are not significantly different from zero.

$$H_0 : CAAR_t = 0$$

The alternate hypothesis states that the CAAR on earnings announcements is significantly different from zero.

$$H_1 : CAAR_t \neq 0$$

Where $CAAR_t$ is the cumulative average abnormal return during the post-transaction period or event window.

## Methodology

The population of interest was all the companies listed on the JSE-ALtX that announced annual earnings between 1 January and 31 December 2009. The target population was extracted from the database of earnings announcements compiled by JSE News Services (SENS).

A purposeful and judgemental sampling method was employed for the study. In order to be included in the target sample, the extracted sample of earnings announcements had to adhere to *all* the inclusion criteria set. In this study, the method of calculating the required returns using the CAPM, with its emphasis on the single-factor beta model, was applied. The event study methodology was employed to test for abnormal performance and market efficiency. The abnormal return is simply the actual return of security *j* in the same period less the calculated required return.

Share data were extracted from McGregor BFANet using McGregor RAID Station. The data required included the daily closing prices for all shares listed on the ALtX that announced earnings between 1 January and 31 December 2009. Closing price data had to be available for at least 1 500 trading days before the earnings announcement of interest in order to compute the companies' beta.

## Event studies

Event study methodology is regarded as a powerful tool in efficient market hypothesis research, and many researchers – namely Aharony and Swary (1980), Dey and Radhakrishna (2008), Louhichi (2008), Kiger (1972), Bhana (1995/96, 2005, 2007), Lonie et al. (1996), Gajewski and Quéré (2001), Kong and Taghavi (2006), Dasilas et al. (2008), Das et al. (2008), Laidroo (2008), Bowman (1983), Cox and Weirich (2002), and Lyroudi, Dasilas and Varnas (2006) – have successfully utilised the tool where security prices respond to new information. Mushidzi and Ward (2004) assert that event study methodology is frequently used to determine whether there is a statistical difference between actual stock returns and required returns surrounding an event.

MacKinlay (1997) asserts that an event study methodology measures the impact of a specific event on the value of a firm. McWilliams and Siegel (1997) state that an event study is a tool that helps to assess the financial impact associated with an 'unanticipated event'. Das et al. (2008: 64) argue that an event study assesses the significance of the economic event on the market value of a firm. Researchers such as Bowman (1983) and Brown and Warner (1985) provide a framework for conducting an event study, and the present research adopted that framework for the research.

## Asset pricing models and market anomalies

The use of the capital asset pricing model (CAPM) to calculate the securities' required returns has been criticised for over a decade. Researchers including Fama and French (1992 1996), Graham and Uliana (2001), Robins, Sandler and Durand (1999), Van Rensburg (2001), Lee and Upneja (2008), and Drew, Naughton and Veeraragavan (2005) argue that a single factor beta model provides little, if any, reasonable explanation for the cross-section of expected security returns.

In this study, the method of calculating the required returns using the CAPM, with its emphasis on the single-factor beta model, was applied. Despite arguments against the model, many researchers still find it practical and reliable. Drew et al. (2005) argue that CAPM does not fully explain the cross-section of return, but up to 61% of the securities' return can be explained by their beta.

Selim (2008) highlights that the inclusion of the risk-free rate in CAPM displays the essence of Islamic financing (namely, the absence of interest payment) and therefore supports the usage of the model in returns calculations. Selim (2008) also believes that the model captures the notion that investors will always prefer higher returns at the lowest possible risk. Galagedera (2007) argues that CAPM still holds if the normality of returns can be achieved, because the mean and the variance are then sufficient to describe the return distribution.

Guan, Hansen, Leikam and Shaw (2007) present evidence that as measurement error in beta is reduced, then the role of beta in explaining the cross-sectional returns increases. The authors further argue that the measurement errors in beta could be due to the fact that some betas can be over- or understated. Gray, Hall, Klease and McCrystal (2009) postulate that the ability of beta to predict future stock returns systematically increases with the length of the estimation window and the application of the Vasicek bias correction. Ingram and Margetis (2010) provide empirical evidence showing that CAPM delivers an acceptable method of estimating the market, namely priced risk of firms. It is therefore believed that enough evidence has been provided to support the use of CAPM. Even though CAPM may not be the best model, evidence suggests that it is still a valid tool to use when measuring securities' required returns.

The most widely accepted form of CAPM is based on the following:

$$E(R)_{jt} = R_{jt} + \beta_j(R_{mt} - R_{jt}) \qquad t = -10, +5 \qquad (1)$$

Where:

$$\beta_j = \frac{Cov(R_j, R_{mt})}{Var(R_{mt})} \qquad (2)$$

In this formulation:

| | | |
|---|---|---|
| $E(R)jt$ | = | the required return for security $j$ on day $t$ |
| $Rmt$ | = | the market return, on day $t$ |
| $Rft$ | = | risk-free rate in period $t$. A long-term (30-year) government bond R186, was utilised in this paper |
| $Cov(R_j, R_{mt})$ | = | is the covariance or correlation coefficient between the returns of an individual stock and the returns on the market |
| $Var(R_{mt})$ | = | is the variance of returns on the market |
| $\beta_j$ | = | is the relative risk of a specific security in relation to the risk of the market. Hitchner (2006) reports that beta measures the volatility of the excess return on individual securities relative to the market as a whole. |

## Sampling method

A purposeful and judgemental sampling method was employed for the study. In order to be included in the target sample, the extracted sample of earnings announcements had to adhere to *all* the following criteria:

- The shares of the announcing firm should have been listed on the ALtX stock exchange and actively traded.
- There should have been a public earnings announcement in the JSE News Services.
- Daily share data must be available to meet the requirements of the empirical testing, which is ten trading days prior to and five trading days after the official announcement date.
- Companies with missing data are excluded from the sample.
- No confounding events should have occurred in the 16-day event window. Firms that made multiple announcements during the 16-day event period are excluded from the sample. Other confounding announcements included the following: BEE announcements; dividends; capital expenditure projects; litigations; share splits; management change (including dismissal or hiring of key members of the executive management team such as the CEO and CFO); restructuring (whether financial, operational or otherwise); directors' share dealings; mergers and acquisitions; and any information or events released in the event window that could potentially affect the share price of a target security.

## Method of data collection

Share data were extracted from McGregor BFANet using McGregor RAID Station. The data required included:

- The daily closing prices for all shares listed on the ALtX that announced earnings between 1 January and 31 December 2009.
- The closing price data for at least 1 500 trading days before the earnings announcement of interest in order to compute the companies' beta.
- Earning announcements, which were extracted from the JSE News Services (SENS). The day on which companies published their earnings on SENS constituted $D_0$.
- SENS announcements, which were reviewed to ascertain any confounding events, as discussed earlier, that could have occurred within the event window, to ensure that the share price movement was due solely to the earnings announcement.

The business press, companies' annual reports and company websites also served as sources of data.

## Data analysis

The event study methodology was employed to test for abnormal performance. The event of interest is the public announcement of earnings, and the event date is the first day on which such an announcement is made. This day is denoted '$Day_0$', herein referred to as $t_0$. The impact on the security's daily closing price was measured over a period of ten trading days prior to the announcement day, and five trading days after the announcement day (referred to as $t$-10 … $t$+5, the *event window*).

The daily share price return for each share in each portfolio was calculated using log-returns. Strong (1992) argues that logarithmic returns are preferred because they are theoretically better when linking together sub-period returns to form returns over a long time, and is given by:

$$R_{jt} = \log(P_{jt} / P_{jt-1}) \quad (3)$$

Where:

$R_{jt}$ = the share price return for security $j$ for day $t$
$P_{jt}$ = the share price of security $j$ at the end of day $t$.

Beta coefficients were calculated for each share in the sample by regressing the share's daily log-function monthly share price return over the five years preceding the

earnings announcement date against the daily returns of each of the 34 companies for the same period.

After calculating the beta coefficients for each security, the required return for each security for each day in the event window was calculated. This was done by using formula (1), the CAPM.

Once the required return for security *j* in period *t* had been calculated, the abnormal return for each selection for each day in the event window was calculated. Abnormal returns were calculated for each security over the 16-day event period, *t* = -10 to +5 trading days, and any significant differences found between actual returns and required market returns were attributed to the information content of earnings announcements. The abnormal return is simply the actual return of security *j* in the same period less the calculated required return:

$$AR_{jt} = R_{jt} - E(R_{jt}) \tag{4}$$

Where:

$AR_{jt}$ = the abnormal return of security *j* in period *t*
$E(R_{jt})$ = the required share price return of security *j* in period *t* as constructed by the returns-generating model
$R_{jt}$ = actual return of security *j* in period *t*.

These above-abnormal returns are summed and averaged cross-sectionally on day *t* as follows:

$$AAR_t = \sum_{j=1}^{N} AR_{jt} / N \tag{5}$$

Where:

N is the number of earnings announcements in the sample at day *t*.

The cumulative average abnormal returns (CAAR) for *t* days are calculated by:

$$CAAR = \sum_{t=-0}^{+5} AAR_t \tag{6}$$

The procedure by Brown & Warner (1985) was followed in the statistical analysis to test the significance of the cumulative average abnormal returns in terms of the null hypothesis that such returns are equal to zero. It follows a *t*-distribution and is formulated as:

$$t_{AAR} = \frac{AAR_t}{\sigma(AAR)/\sqrt{n}} \tag{7}$$

The statistical significance of the cumulative abnormal returns is given by:

$$t_{CAAR} = \frac{CAAR_{jt}}{\sigma(AAR)\ d^{0.5}} \quad (8)$$

Where $\sigma(AAR)$ is the estimated standard deviation, $d$ stands for the total number of days for which AAR is cumulative.

The significance level was set at a 1% margin of error to determine whether the CAAR differed statistically significantly from zero ($H_0$: $CAAR_t = 0$).

## Research results

The following sections present the descriptive analysis of the study as well as the statistical analysis undertaken to test the research hypothesis.

### Description of the sample

The sample distribution was as follows: construction industry (21%), followed by IT and computer services (15%), then financial services (12%), telecommunication and business support (9% each), mining companies (6%); companies in waste management, transportation, industrial supplies, steel, electronics, electricity, hospitality, consumer services, food products and personal products industries (all with a 3% sample representation).

### Analysis of the data

It can be noted from Figure 1 that the ALtX index was in a 'bear market' for the whole of 2009, with the market losing almost 80%. It can also be noted that the worst performance was in the first and last quarters, and that the index stabilised somewhat in the middle of the year.

It can further be observed that over the entire 16-day event window, the mean return was -3.12% and the median return was -2.18%. It can also be observed that the average returns were negatively skewed and the distribution of the AAR was platykurtic. Most of the returns in the event window were in the range of -2.9% and -2%, which is also where the median lies. These results are shown in Table 1.

Table 2 presents the results of the share price response to earnings announcements for the event window (a 16-day event window). As can be seen, average abnormal returns for each of the 16 event days were negative. However, not all the results were


**Figure 1:** ALtX performance during 2009

**Table 1:** Statistical measure of the AAR

| Statistical measure | Value |
|---|---|
| Mean | -3.12% |
| Median | -2.18% |
| Skewness | -1.063 |
| Kurtosis | 0.84 |
| Mode | -2.9% to -2% |

statistically significant; days $t_{-10}$, $t_{-8}$, $t_{-7}$, $t_{-3}$, and $t_{+5}$ were statistically significant at the 5% significance level (-2.72%, -3.02%, -3.45%, -3.53% and -4.53% respectively). Similarly, the results of days $t_{-5}$ and $t_{+2}$ were statistically significant at the 1% significance level (-6.22 and -6.85 respectively). Figure 2 presents a graphical representation of these results.

Table 2 and Figure 3 also present the cumulative average abnormal return results for the entire 16-day event window. Interestingly, the results of only days $t_{-10}$ (-0.4) and $t_{-9}$ (-0.78) were not statistically significant; and $t_{-8}$ (- 1.82) and $t_{-7}$ (- 2.53) were significant at the 10% and 5% levels respectively. From day $t_{-6}$ until day $t_{+5}$, the results were statistically significant at the 1% level of significance. It can also be noted that the sample showed an average cumulative loss of 49.9% during the entire event period.

**Table 2:** 16-day event period results and statistical analysis

| Event day | AAR | AAR t-statistics (2-tailed) | CAAR | CAAR t-statistics (2-tailed) | SD |
|---|---|---|---|---|---|
| *t*-10 | -2.72% | -2.3179** | -2.72% | - 0.40 | 0.069 |
| *t*-9 | -1.67% | -1.2170 | -4.40% | - 0.78 | 0.080 |
| *t*-8 | -3.02% | -2.4967** | -7.42% | - 1.82* | 0.071 |
| *t*-7 | -3.45% | -2.3402** | -10.86% | - 2.53** | 0.086 |
| *t*-6 | -1.30% | -0.9212 | -12.17% | - 3.30*** | 0.082 |
| *t*-5 | -6.22% | -2.7367*** | -18.38% | - 3.40*** | 0.132 |
| *t*-4 | -2.43% | -1.3793 | -20.81% | - 5.36*** | 0.103 |
| *t*-3 | -3.53% | -2.1097** | -24.34% | - 7.06*** | 0.098 |
| *t*-2 | -2.90% | -1.1575 | -27.24% | - 5.60*** | 0.146 |
| *t*-1 | -0.98% | -0.4941 | -28.22% | - 7.75*** | 0.115 |
| *t*0 | -1.69% | -0.9451 | -29.90% | - 9.52*** | 0.104 |
| *t*+1 | -3.94% | -1.3716 | -33.84% | - 7.01*** | 0.167 |
| *t*+2 | -6.85% | -2.9247*** | -40.69% | - 10.75*** | 0.136 |
| *t*+3 | -2.19% | -1.4878 | -42.88% | - 18.66*** | 0.086 |
| *t*+4 | -2.53% | -1.5651 | -45.41% | -18.69*** | 0.094 |
| *t*+5 | -4.53% | -2.3137** | -49.94% | -17.49*** | 0.114 |

**Notes:** The table presents the test statistics (one sample t-test). *, **, and *** denote statistical significance at the 10%, 5% and 1% levels (two-tailed test) respectively for the 16-day event period.

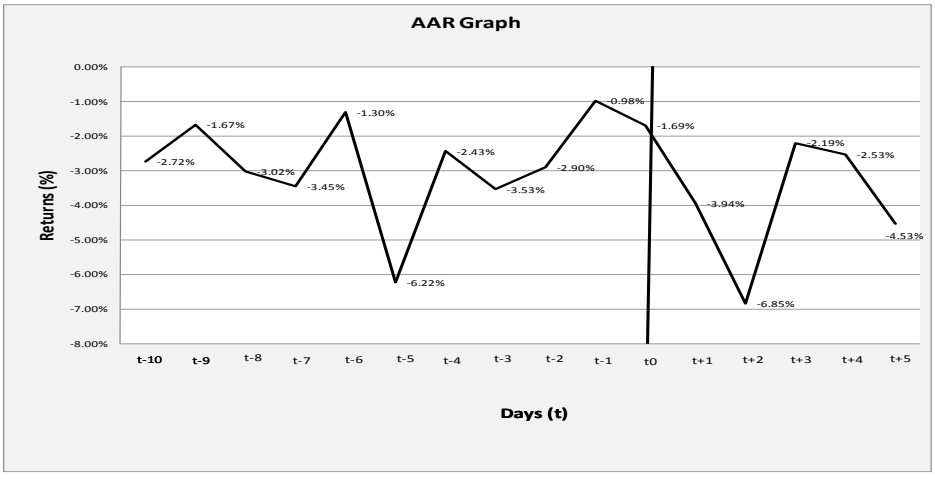


**Figure 2:** Graphical representation of AAR for the 16-day event window

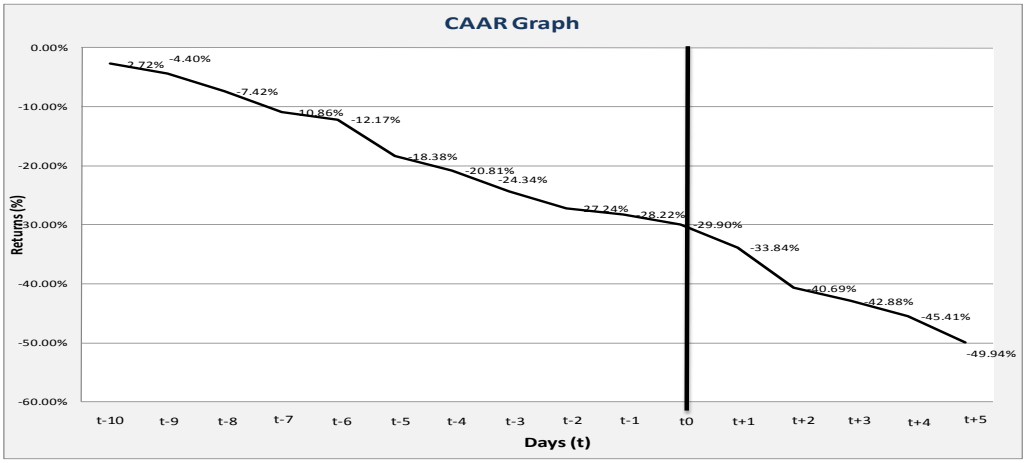


**Figure 3:** Graphical representation of CAAR for the 16-day event window

Table 3 shows the results for a five-day event window, from day $t_{-2}$ to $t_{+2.}$ The share price reaction for both average abnormal returns and the cumulative average abnormal returns for day $t_{+5}$, (-6.85%: -2.925 and -16.34%: -2.678) were the only statistically significant results.

**Table 3:** Five-day event period results and statistical analysis

| Event day | AAR | AAR t-statistics (2-tailed) | CAAR | CAAR t-statistics (2-tailed) | SD |
|---|---|---|---|---|---|
| *t*-2 | -2.90% | -1.158 | -2.90% | -0.199 | 0.146 |
| *t*-1 | -0.98% | -0.494 | -3.87% | -0.476 | 0.115 |
| *t*0 | -1.69% | -0.945 | -5.56% | -0.924 | 0.104 |
| *t*+1 | -3.94% | -1.372 | -9.50% | -1.135 | 0.167 |
| *t*+2 | -6.85% | -2.925*** | -16.34% | -2.678*** | 0.136 |

**Notes:** The table presents the test statistics (one sample t-test). *, **, and *** denote statistical significance at the 10%, 5% and 1% levels (two-tailed test) respectively for the five-day event period.

Having observed that the performance of ALtX during 2009 was poor on average, and that on average this study seems to suggest that the earnings announcements observed here were bad news, then these study findings coincide with those of Lonie et al. (1996), Louhichi (2008), Lakhal (2008) and Gajewski and Quéré (2001), in that earnings announcements of bad news gave rise to negative share price reaction.

However, these findings differ fundamentally from those of:

- Kong and Taghavi (2006), in that they found that annual earnings announcements led to positive share price reaction. No dividends announcements were included. Similar findings were reported by Sponholtz (2008).
- Chan et al. (2009), in that positive reactions were observed; however, dividends were also included in this study. The same applies to Das et al. (2008).
- Das et al. (2008), who found neither positive nor negative reactions to earnings announcements, irrespective of the quality of news announced.

## Conclusion

This study was undertaken to achieve the following objectives:

- To investigate whether there are any significant abnormal returns (whether positive or negative) related to the public announcement of earnings
- To establish whether the efficient capital market hypothesis applies to the small ALtX market.

To achieve these objectives, it was hypothesised that that cumulative average abnormal returns (CAAR) due to earnings announcements are not significantly different from zero.

It has been proved in this study that the null hypothesis is invalid. Therefore, in line with the findings, the null hypothesis is rejected in favour of the alternate hypothesis. Empirical evidence demonstrates that there is substantial negative share price reaction to earnings announcements on the ALtX stock market. It was also observed that both 16-day and five-day event periods lead to significant cumulative loss of 49.9% and 16.3% respectively.

The study concludes that, for the sample chosen, it was proved that earnings announcements during a recessionary period result in negative share price reaction, and subsequently, share market erosion of the selected sample.

The study was also intended to contribute to the existing literature on earnings announcements by analysing the information content of earnings announcements in a small South African stock market. It was also intended to shed light on whether the small JSE-ALtX market is efficient. The study has indicated that the information content of earnings is quite noticeable. No price recovery was observed in this study. It can therefore be argued that market efficiency, at least in its strong form, is not observed in the ALtX stock exchange. The ALtX thus show the weak form of market efficiency.

## Implications and recommendations

This study suggests that there is a weak form of capital market efficiency, as supported by the significant negative abnormal returns after the announcements.

The findings are useful to researchers, practitioners and investors with an interest in the strategic decision-making of firms listed on the ALtX. It is observed that once returns are on a down-slide, they do not seem to recover quickly, and invested capital can be eroded. In this study alone, share price as a proxy for shareholder value led to up to 50% loss of value, and the results were found to be very significant.

It is recommended that the study be conducted again with an extended event period and that other asset pricing models also be applied.

## Limitations of the study

The study had several limitations, which open the way for further research in this area. The report acknowledges the following limitations:

- All mediums of disclosure other than public announcements were excluded, and only those announcements recorded on SENS were considered for the study.
- The sampling method used was non-probabilistic. The study was therefore unable to test external validity, and conclusions could be drawn only in relation to the sample.
- The reliability of the study could have been improved if other measuring tools had been applied; that is, instead of using only CAPM for measuring required returns, methods such as the market model and/or three factor model for required returns could have been used, particularly given the criticism levelled against beta not being able to fully explain the securities' returns.
- The study focused essentially on the share price movement in relation to the public announcement of earnings. The study did not separate 'good' from 'bad' earnings announcements. As a result, the bad announcements seem to have outweighed all the good announcements. Again, there are a number of outliers, and it is known that these have a serious impact on the mean (AAR, in this case), which will impact on the research results.
- The study did not deal with quarterly and/or half-yearly earnings announcements, and the information content of those earnings was therefore not captured in this study.
- The study had a relatively small sample (n=34).
- The 16-day event window did not appear to be able to illustrate when rectification or price recovery would occur.

## References

Abdmoulah, W. 2010. 'Testing the evolving efficiency of Arab stock markets', *International Review of Financial Analysis*, 19(1): 25–34.

Abedini, B. 2009. 'Weak-form efficiency: Stock market in the Gulf Co-operation Council countries', *SCMS Journal of Indian Management,* 6(3): 15–28.

Aharony, J. & Swary, I. 1980. 'Quarterly dividend and earnings announcements and stockholders' returns: An empirical analysis', *Journal of Finance,* 35(1): 1–12.

Asamoah, G. 2010. 'The impact of dividend announcement on share price behaviour in Ghana', *Journal of Business & Economics Research,* 8(4): 47–58.

Asiri, B. 2008. 'Testing weak-form efficiency in the Bahrain stock market', *International Journal of Emerging Markets,* 3(1): 38–53.

Ball, R. & Shivakumar, L. 2008. 'How much new information is there in earnings?' *Journal of Accounting Research,* 46(5): 975–1016.

Ball, R. & Brown, P. 1968. 'An empirical evaluation of accounting income numbers', *Journal of Accounting Research,* 6(2): 159–178.

Barker, R. & Imam, S. 2008. 'Analysts' perception of "earnings quality"', *Accounting and Business Research,* 38(4): 313–328.

Basistha, A. & Kurov, A. 2008. 'Macroeconomic cycles and the stock market's reaction to monetary policy', *Journal of Banking and Finance,* 32(12): 2606–2616.

Bernard, V. & Thomas, J. 1989. 'Post earnings announcement drift: Delayed price response or risk premium', *Journal of Accounting Research,* 27: 1–36.

Bhana, N. 1995/96. 'The share market reaction to earnings announcements: A test of the efficiency of the Johannesburg Stock Exchange', *Investment Analysts*, 42: 45–57.

Bhana, N. 2005. 'The share price reaction to management buyout announcements of companies listed on the JSE Securities Exchange', *Investment Analyst Journal,* 62: 19–30.

Bhana, N. 2007. 'The market reaction to open market share repurchases announcements: The South African experience', *Investment Analysts Journal*, 65: 25–36.

Black, F. 1980. 'The magic in earnings: Economic earnings versus accounting earnings', *Financial Analysts Journal,* November–December: 19–24.

Bowman, R.G. 1983. 'Understanding and conducting event studies', *Journal of Business Finance and Accounting,* 10(4): 561–584.

Brown, S.J. & Warner, J.B. 1985. 'Using daily stock returns: the case of event studies', *Journal of Financial Economics,* 14: 3–31.

Chai, M.L. & Tung, S. 2002. 'The effect of earnings announcement timing on earnings management', *Journal of Business Finance and Accounting,* 29(9&10): 1337–1354.

Chan, A.L.C., Lin, S.W.J. & Strong, N. 2009. 'Accounting conservatism and the cost of equity capital: UK evidence', *Managerial Finance,* 35(4): 325–345.

Chan, H., Faff, R. & Ramsay, A. 2005. 'Firm size and the information content of annual earnings announcement: Australian evidence', *Journal of Business Finance and Accounting,* 32(1): 211–253.

Charles, A. & Darné, O. 2009. 'The random walk hypothesis for Chinese stock markets: Evidence from variance ratio tests', *Economic Systems,*33(2): 117–126.

Chatuverdi, H.O. 2000. 'Empirical anomalies based on unexpected earnings: The Indian experience', *ICFAI University Journal of Accounting Research,* VI(1): 1–13.

Cheon, Y.S, Christensen, T.E. & Bamber, L.S. 2001. 'Factors associated with differences in the magnitude of abnormal returns around NYSE versus NASDAQ firms' earnings announcements', *Journal of Business Finance and Accounting,* 28(9): 1073–1108.

Chordia, T. & Shivakumar, L. 2005. 'Inflation illusion and post-earnings announcement drift', *Journal of Accounting Research,* 43(4): 521–556.

Chordia, T., Goyal, A., Sadka, G., Sadka, R. & Shivakumar, L. 2009. 'Liquidity and the post-earnings announcement drift', *Financial Analysts Journal,* 65(4): 18–32.

Christensen, T.E., Smith, T.Q. & Stuerke, P.S. 2004. 'Public predisclosure information, firm size, analyst following, and market reactions to earnings announcements', *Journal of Business Finance and Accounting,* 31(7): 951–984.

Cox, R.A.K. & Weirich, T.R. 2002. 'The stock market reaction to fraudulent financial reporting', *Managerial Auditing Journal,* 17(7): 374–382.

Cready, W.M. & Gurun, U.G. 2010. 'Aggregate market reaction to earnings announcements', *Journal of Accounting Research,* 48(2): 289–334.

Das, S., Pattanayak, J.K. & Pathak, P. 2008. 'The effect of quarterly earnings announcements on Sensex: A case with clustering of events, *ICFAI University Journal of Accounting Research,* 7(4): 64–78.

Dasilas, A., Lyroudi, K. & Ginoglou, D. 2008. 'Joint effects of interim dividend and earnings announcements in Greece', *Studies in Economic Finance,* 25(4): 212–232.

Deshmukh, S., Fatemi, A. & Fooladi, I.J. 2008. 'Complexity of information and trading behavior: The case of dividend increase announcements', *Journal of Economic Psychology,* 29(1): 1–18.

Dey, M.K. & Radhakrishna, B. 2008. 'Who profits from trading around earnings announcements? Evidence from TORQ data', *Journal of Asset Management,* 9(4): 300–308.

Drew, M.E. Naughton, T. & Veeraragavan, M. 2005. 'Pricing of equities in China: Evidence from Shanghai Stock Exchange', *Managerial Finance,* 31(12): 46–57.

Fama, E.F. & French, K.R. 1992. 'Cross-section of expected returns', *Journal of Finance,* 47(2): 427–465.

Fama, E.F. & French, K.R. 1996. 'Multifactor explanations of asset pricing anomalies', *Journal of Finance*, 51(1): 55–84.

Fama, E.F., Fisher, L., Jensen, M.C. & Roll, R. 1969. 'The adjustment of stock prices to the new information', *International Economic Review,* 10(1): 1–21.

Floros, C. & Vougas, D.V. 2008. 'The efficiency of Greek stock index futures market', *Managerial Finance,* 34(7): 498–519.

Foster, G., Olsen, C. & Shevlin, T. 1984. 'Earnings releases, anomalies and the behaviour of security prices', *Accounting Review,* 59(4): 574–603.

Gajewski, J. & Quéré, B.P. 2001. 'The information content of earnings and turnover announcements in France', *European Accounting Review,* 10(4): 679–704.

Galagedera, D.U.A. 2007. 'A review of asset pricing models', *Managerial Finance,* 33(10): 821–832.

Graham, M. & Uliana, E. 2001. 'Evidence of value-growth phenomenon on the Johannesburg Stock Exchange', *Investment Analysts Journal,* 53: 7–18.

Gray, S., Hall, J., Klease, D. & McCrystal, A. 2009. 'Bias, stability, and the predictive ability in the measurement of systematic risk', *Accounting Research Journal,* 22(3): 220–236.

Grubel, H.G. 1979. 'The Peter Principle and the efficient market hypothesis', *Financial Analysts Journal,* November–December: 72–75.

Guan, L., Hansen, D.R., Leikam, S.L. & Shaw, J. 2007. 'Stable betas, size, earnings-to-price, book-to-market and the validity of the capital asset pricing model', *Managerial Finance,* 33(8): 595–614.

Guidi, F. 2010. 'Day-of-the-week effect and market efficiency in the Italian Stock Market: An empirical analysis', *IUP Journal of Applied Finance,* 16(2): 5–32.

Hitchner, J. 2006. 'Cost of capital/Rates of return', In Hitchner, J. (ed.), *Financial Valuation: Application and Models* (2nd edition). New Jersey: John Wiley & Sons.

Hung, J-C., Lee, Y-H. & Pai, T-Y. 2009. 'Examining market efficiency for large- and small-capitalization of TOPIX and FTSE stock indices', *Applied Financial Economics* 19(9): 735–744.

Hussin, B.M., Ahmed, A.D. & Ying, T.C. 2010. 'Semi-strong form efficiency: Market reaction to dividend and earnings announcements in Malaysian stock exchange', *IUP Journal of Applied Finance,* 16(5): 36–60.

Ingram, M. & Margetis, S. 2010. 'A practical method to estimate the cost of equity capital for a firm using cluster analysis', *Managerial Finance,* 36(2): 160–167.

Jarrett, J.E. 2008. 'Random walk, capital market efficiency and predicting stock returns for Hong Kong Exchanges and Clearing Limited', *Management Research News,* 31(2): 142–148.

Jarrett, J.E. & Kyper, E. 2006. 'Capital market efficiency and the predictability of daily returns', *Applied Economics,* 38(6): 631–636.

Johnson, M.F. 1999. 'Business cycle and the relation between security returns and earnings', *Review of Accounting Studies,* 4: 93–117.

Kiger, J. 1972. 'An empirical investigation of NYSE volume and price reactions to the announcement of quarterly earnings', *Journal of Accounting Research,* 10(1): 113–128.

Kim, J.H. & Shamsuddin, A. 2008. 'Are Asian stock markets efficient? Evidence from new multiple variance ratio tests', *Journal of Empirical Finance,* 15(3): 518–532.

Kong, S. & Taghavi, M. 2006. 'The effect of annual earnings announcements on the Chinese Stock Markets', *International Advances in Economic Research,* 12: 318–326.

Laidroo, L. 2008. 'Public announcement induced market reactions on Baltic exchanges', *Baltic Journal of Management,* 3(2): 174–192.

Lakhal, F. 2008. 'Stock market liquidity and information asymmetry around voluntary earnings disclosures', *International Journal of Managerial Finance,* 4(1): 60–75.

Laopodis, N.T. 2003. 'Financial market liberalization and stock market efficiency: The case of Greece', *Managerial Finance,* 29(4): 24–41.

Laopodis, N.T. 2009. 'Fiscal policy and stock market efficiency: Evidence for the United States', *Quarterly Review of Economics and Finance,* 49(2): 633–650.

Lee, S. & Upneja, A. 2008. 'Is the capital asset pricing model (CAPM) the best way to estimate cost of equity for the lodging industry?', *International Journal of Contemporary Hospitality Management,* 20(2): 172–185.

Lev, B. 1989. 'On the usefulness of earnings and earnings research: Lessons and directions from two decades of empirical research', *Journal of Accounting Research,* 27: 153–201.

Lim, K-P. 2009. 'Weak-form market efficiency and nonlinearity: Evidence from Middle East and African stock indices', *Applied Economics Letters*, 16(5): 519–522.

Lim, K-P. & Brooks, R. 2009. 'Are Chinese stock markets efficient? Further evidence from a battery of nonlinearity tests', *Applied Financial Economics*, 19(2): 147–155.

Lim, K., Brooks, R.D. & Hinich, M.J. 2008. 'Nonlinear serial dependence and the weak-form efficiency of Asian emerging stock markets', *Journal of International Financial Markets, Institutions and Money,* 18(5): 527–544.

Lim, K., Brooks, R.D. & Kim, J.H. 2008. 'Financial crisis and stock market efficiency: Empirical evidence from Asian countries', *International Review of Financial Analysis,* 17(3): 571–591.

Livnat, J. & Mendenhall, R.R. 2006. 'Comparing the post-earnings announcement drift for surprises calculated from the analyst and time series forecasts', *Journal of Accounting Research,* 44(1): 177–205.

Lonie, A.A., Abeyratna, G., Power, D.M. & Sinclair, C.D. 1996. 'The stock market reaction to dividend announcement. AUK study of complex market signals', *Journal of Economic Studies,* 23(1): 32–52.

Louhichi, W. 2008. 'Adjustment of stock prices to earnings announcement: Evidence from Euronext Paris', *Review of Accounting Finance,* 7(1): 102–115.

Lyroudi, K. & Dasilas, A. & Varnas, A. 2006. 'The valuation effects of stock splits in NASDAQ', *Managerial Finance,* 32(5): 401–414.

MacKinlay, A.C. 1997. 'Event studies in Economics and Finance', *Journal of Economic Literature,* 35(1): 13–39.

Malkiel, B.G. 2005. 'Reflections on the efficient market hypothesis: 30 years later', *Financial Review,* 40: 1–9.

Mallikarjunappa, T. & Manjunatha, T. 2009. 'Stock price reactions to dividend announcements', *Journal of Management and Public Policy,* 1(1): 43–56.

McWilliams, A. & Siegel, D. 1997. 'Event studies in management research: Theoretical and empirical issues', *Academy of Management Journal,* 40(3): 626–657.

Mendenhall, R. 1991. 'Evidence of possible underweighting of earnings-related information', *Journal of Accounting Research,* 29: 394–417.

Metghalchi, M., Chang, Y. & Marcucci, J. 2008. 'Is the Swedish stock market efficient? Evidence from some simple trading rules', *International Review of Financial Analysis,* 17(3): 475–490.

Mittal, S. & Jain, S. 2009. 'Stock market behaviour: Evidences from Indian market', *Vision,* 13(3): 19–29.

Mushidzi, T.B. & Ward, M. 2004. 'Abnormal returns for cash vs share-funded acquisitions', *Investment Analysts Journal,* 60: 17–32.

Nthoesane, M.G. 2011. *Share Price Reaction to BEE Announcement on the JSE: A Short-Term Test for Market Efficiency.* Saarbrücken, Germany: VDM Verlag Dr Müller GmbH & Co. KG.

Ozdemir, Z.A. 2008. 'Efficient market hypothesis: Evidence from a small open-economy', *Applied Economics,* 40(5): 633–641.

Putman, R.L., Griffin, R.B. & Kilgore, R.W. 2008. 'The impact of earnings management on capital markets: Ethical consideration of the players', *Journal of Legal, Ethical and Regulatory Issues,* 11(2): 139–145.

Robins, E.M., Sandler, M. & Durand, F. 1999. 'Inter-relation between the January effect, market capitalisation and value investment strategies on the JSE', *Investment Analysts Journal,* 50: 53–61.

Sappideen, R. 2009. 'The paradox of securities markets efficiency: Where to next?', *Singapore Journal of Legal Studies,* July: 80–108.

Selim, T.H. 2008. 'An Islamic capital asset pricing model', *Humanomics,* 24(2): 122–129.

Sharma, A. 2009, 'Impact of public announcement of open offer on shareholders return: An empirical test for efficient market hypothesis', *IUP Journal of Applied Finance,* 15(11): 37–51.

Simpson, M., Emery, J. & Moreno, J. 2009. 'Overreaction and under-reaction to REIT dividend announcements and the role of monetary policy', *Journal of Real Estate Portfolio Management,* 15(3): 289–298.

Sponholtz, C. 2008. 'The information content of earnings announcements in Denmark', *International Journal of Managerial Finance,* 4(1): 4–36.

Stanley, D. & Samuelson, B. 2009. 'The efficient market hypothesis, price multiples, and the Austrian Stock Market', *Journal of Global Business Issues*, 3(1): 183–192.

Strong, N. 1992. 'Modeling abnormal returns: A review article', *Journal of Business Finance and Accounting*, 19: 533–553.

Van Rensburg, P. 2001. 'A decomposition of style-based risk on the JSE', *Investment Analysts Journal,* 54: 45–60.

Varamini, H. & Kalash, S. 2008. 'Testing market efficiency for different market capitalization funds', *American Journal of Business,* 23(2): 17–26.

Wang, Y. & Corbertt, R.B. 2008. 'Market efficiency: Evidence from market reactions of insurance industry stocks to the September 11 2001 event', *Journal of Insurance Issues,* 31(2): 152–167.

Zunino, L., Zanin, M., Tabak, B.M., Pérez, D.G. & Rosso, O.A. 2009. 'Forbidden patterns, permutation entropy and stock market inefficiency', *Physica A: Statistical Mechanics and its Applications,* 388(14): 2854–2864.