INFORMATION THEORY AND WEAK MARKET EFFICIENCY: EVIDENCE FROM THE GREEK STOCK MARKET

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Abstract

We use methods and tools from Information Theory to gauge the weak form of efficiency in the Greek stock market with respect to the proportions of advancing, declining and remaining unchanged issues. Comparing the results of the present paper with previous works from other academic researchers on the same subject, we conclude that the Greek stock market exhibits (on average) significantly less efficiency than other large stock markets with respect to the abovementioned proportions and in particular it is found that the Athens Stock Exchange relies significantly in a memory of 75 trading days of which the 30 most recent are the most influential. Our findings advocate previous research reports relative to the hypothesis that the comparably larger markets are generally more efficient than the small ones.

Keywords: market, Greece, stocks

JEL Classification: G10, G14

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Introduction

The concept of weak form of efficiency in a stock market is of high importance to investors and fund managers since lack of significant weak efficiency indicates that not all past prices of a stock are reflected in today's price. In effect, investors and fund managers could enhance their performance in this market using algorithmic methods to exploit the information contained in past prices.

During the last decade a number of academic studies controvert the weak form of efficiency in the Greek Stock Market. In late nineties Barkoulas and Travlos (1998) used daily data of the 30 most marketable stocks of the Athens Stock Exchange (ASE) from January 1981 to December 1990 and employed ARq(p) and a GARCH (1,1) models to conclude that there is no evidence in support of a chaotic structure in ASE. Later, Barkoulas, Baum and Travlos (2000) used weekly returns of the 30 most marketable Greek stocks from 1988 to 1990 and showed that there is evidence of long memory in ASE. Panas (2001) examined the daily returns of 13 Greek stocks, and he found statistically significant long memory in most of the series. Siourounis (2002) used GARCH type models to show that the weak form of efficiency does not hold for ASE and Niarchos and Alexakis (2003) argued that the ASE exhibits specific intraday price patterns which can be exploited. Later Antoniou, Galariotis and Spyrou (2005) presented evidence of contrarian profits in ASE using weekly data from 1990 to 2000 and Panagiotidis (2005) used BDS, McLeod-Li, Engle LM, Tsay and Bicovariance tests to show that the random walk hypothesis is rejected for the Greek stock market even after the introduction of the Euro. Fillis (2006) also supported that the ASE was not an efficient market from 2000 to 2002 due to volatility clustering. There are of course other academic studies that advocate on a random walk and chaotic Greek stock market. Laopodis (2004) for example employed cointegration and regression analysis to support that the ASE was operating as a random walk even before any market liberalization announcements were made, while in a more recent paper Saraidaris and Margaris (2008) performed Lyapunov exponent tests in Bank stock and Indices returns of the ASE from 1999 to 2006 to show that there is a weak but clear evidence of chaos in the Greek Stock Market.

It is interesting however that a paradox arises from some of these researches. In the work of Saraidaris and Margaris, for example, it was argued that there is a slightly stronger evidence of chaos before the classification of MSCI Greece Index to a developed market index and in the paper of Panagiotidis it came up that the lower capitalization index FTSE/ASE small cap is more efficient compared to the large and medium capitalization indices. The paradox here is that according to the efficient market hypothesis the unpredictability of markets relies heavily in the instantaneous distribution and assimilation of information so, there should be more profound efficiency in matured and heavily traded markets rather than in small and somehow isolated ones due to lower cost of information, lower cost of trading and more precise determination of arbitrage opportunities.

The aim of the present paper is to take a slightly different path and examine the weak form of efficiency of the Greek stock market in its entirety through the study of the proportions of advancing, declining and remaining unchanged issues (hereafter referred to as "ADU fractions") of ASE from the perspective of Information Theory. This is an original study for the ASE and contributes to our understanding of the Greek stock market not only in isolation but also with respect to the other world stock markets. In particular, since similar studies have been performed by various researchers to examine the efficiency of some American, European and Asian stock markets, direct comparisons between these markets and the Greek market will be made.

1. Review of past studies for the ADU fractions and the Theil-Leenders test

The numbers of advancing, declining and remaining unchanged issues in a stock market has long been used and proposed by practitioners as aiding tools for forecasting (see for example Freeman (1963), Granville (1961) and Kaufman (1998)). The reliance of practitioners to these numbers sparked academics to study whether it is of value taking them into account for investment or trading purposes. Their use either as independent numbers or incorporated into a formula as prediction tools for future price values seems to be worthless. Zakon and Pennypacker (1968), for example, studied the forecasting ability of the Advanced-Declined line (cumulative sum of advanced issues minus declined issues) in daily and weekly data from the S&P 500 index and concluded that it has no forecasting value.

While the numbers of advancing declining and remaining unchanged issues seem to be of no value as forecasting tools for future stock prices, there is evidence that the successive values of the proportions of advancing, declining and remaining unchanged issues exhibit considerable positive dependence in some stock markets. Theil and Leenders (1965) studied successive values of the ADU fractions for 1,007 days from the Amsterdam Stock Exchange using tools from Information Theory (originally developed by Shannon (1959)) and found significant positive dependence. In particular, they stated that the best prediction for each one of the fractions for tomorrow is halfway between its long average and its observed value of today indicating that the Amsterdam stock exchange has a memory of one day for these fractions. The findings of Theil and Leenders had immediate impact in the validity of the random-walk model at least in the Amsterdam stock exchange.

A similar study concerning the ADU fractions was performed by Fama (1965). Fama studied the ADU fractions for 2,625 trading days (from June 2, 1952 to October 29, 1962) from the New York stock exchange (N.Y.S.E.) and, as in the case with the Amsterdam exchange, he found positive dependence between the successive values of the fractions but of lesser degree and concluded that "the degree of dependence for the N.Y.S.E. is not strong, in that it does not seem to provide the basis for powerful prediction procedures". It is remarkable however that the findings of Fama were in accordance with those of Theil and Leeders for the long averages of the ADU fractions. Both the Amsterdam stock exchange and N.Y.S.E. showed 40%, 40% and 20% as proportions of advancing, declining and remaining unchanged issues respectively. Also, the best prediction for each one of the ADU fractions for tomorrow in N.Y.S.E. was found by Fama to be the sum of 70% of its long average with the 30% of its observed value of today, indicating that, as in case of the Amsterdam exchange, the N.Y.S.E. has a weak memory of one day for these fractions.

The ADU fractions of N.Y.S.E were studied again later by Philippatos and Nawrocki (1973) using price data from 1,988 trading days (from October 1, 1963 to September 30, 1971). Employing Theil-Leenders test Philippatos and Nawrocki argued that the N.Y.S.E. stock exchange shows much more dependency on a one-day memory for the ADU fractions during the 1960s than the dependency found by Fama for the 1950s.

A more recent study of ADU fractions for Stock Exchanges of far east was performed by Hai Hong (1978) using weekly data. In addition to serial correlation and run tests Hong employed the same methods of Information Theory used Theil and Leenders and concluded that amongst Australia, Hong Kong, Japan and Singapore markets, Japan exhibits the highest market efficiency. Since the Japanese market is the largest of these markets, Hong suggested that the larger markets are generally more efficient.

1.1. The Theil-Leenders test

The Theil-Leenders test based on Information Theory gauges the magnitude the observed ADU fractions for a day predict the ADU fractions of the next day. Let $q_{1,t}$, $q_{2,t}$ and $q_{3,t}$ be the proportions of advancing, declining and remaining constant issues respectively in period t and $p_{1,t}$, $p_{2,t}$, $p_{3,t}$ be their corresponding predicting values derived by a rule based upon the values of the fractions up to period $(t-1)$. The inaccuracy of the predictions is quantified by Tehil and Leenders (1965) with the *Information Inaccuracy measure* $I(q:p)$ which is defined by:

$$I(q:p)_t = \sum_{i=1}^{3} q_{i,t} \log_2\left(\frac{q_{i,t}}{p_{i,t}}\right) \tag{1}$$

Simply stated, the ADU fractions $q_{1,t}$, $q_{2,t}$ and $q_{3,t}$ are used not as independent variables but as probabilities (which make sense since they are incompatible and they sum up to *1*). The $I(q:p)_t$ then measures the information gained between the projected probabilities $p_{1,t}, p_{2,t}, p_{3,t}$ and the actual probabilities $q_{1,t}$, $q_{2,t}$, $q_{3,t}$ and provides a metric of inaccuracy of the predictions for period t. The less the $I(q:p)_t$ is, the more accurate are the predictions for the period t.

The Average Information Inaccuracy $\overline{I(q:p)}$ of the predictions is defined as the long arithmetic average of $I(q:p)_t$:

$$\overline{I(q:p)_t} = \frac{1}{T}\sum_{t=1}^{T} I(q:p)_t \tag{2}$$

where $t = 0, 1, 2, \ldots, T$ are the trading periods for which the ADU fractions are available.

1.2. Prediction rules and results from previous researches

Theil and Leenders, as well as Fama, used a class of simple prediction rules which were based upon a front weighted moving average of $q_{i,t}$ and its long average. More precisely, they considered and examined the Average

Information Inaccuracy for the following prediction rules

$$p_{i,t} = a \cdot \left[\frac{\sum_{j=1}^{N} (N - j + 1) \cdot q_{i,(t-j)}}{\frac{1}{2} N(N+1)} \right] + (1 - a) \cdot \overline{q_{i,t}} \qquad (3)$$

where N is a positive integer, $\overline{q_{i,t}} = \frac{1}{t} \sum_{j=1}^{t} q_{i,j}$ and a is real number such that $0 \leq a \leq 1$.

Amongst the various N's and a's, Theil and Leenders found that for the Amsterdam stock exchange the minimum $\overline{I(q:p)}$ is realized when $N = 1$ and $a = 0.477$. The minimum $\overline{I(q:p)}$ was found to be 0.0535 which is about 22% below that of the case $a = 0$ (note that when $a = 0$, rule (1) becomes $p_{i,t} = \overline{q_i}$ indicating that no real prediction is being made). Also, since the minimum $\overline{I(q:p)}$ is realized when $N = 1$, Theil and Leenders concluded that the Amsterdam Stock Exchange has a memory of one day as far as the ADU fractions is concerned.

On the other hand, Fama found that a minimum $\overline{I(q:p)}$ of 0.056 for the N.Y.S.E. is realized when $N = 1$ and $a = 0.3$. The value of 0.056 was only 10,1% below the average information inaccuracy of the naive procedure implied by $a = 0$ in (1) and Fama concluded that the low value of 0.3 for a and the small reduction of $\overline{I(q:p)}$ indicates that no significant predictions can be made with respect to the ADU fractions for the N.Y.S.E.

As far as the eastern stock markets is concerned, Hong (1978) reports that when weekly data are considered, the minimum $\overline{I(q:p)}$ is also realized when $N = 1$ in the markets of Australia, Hong Kong, Japan and Singapore. The corresponding minimum $\overline{I(q:p)}$ were 0.249, 0.251, 0.246 and 0.282 respectively whereas the reductions in $\overline{I(q:p)}$ between the case $a = 0$ and the minimum cases were found by Hong to be 1.6%, 14.3%, 0.4% and 10.2% respectively.

2. Data and Methodology

In order to examine the average information inaccuracy of the prediction rules defined in equation (3), data from 3,996 trading days (15 calendar years) of the Athens Stock Exchange (from January 2, 1995 to December 31, 2010) were used and daily closing prices for its stocks were taken from Reuters database. The data set includes several significant periods for the Greek stock market. More precisely, in the mid to late 1990s the Greek government put in place several additional laws in a continuing effort to liberalize the market and in the late 1990s and early 2000s the ASE entered a severe "bear" phase which lasted three years. The market then recovered in small pace and began being dominated by foreign investors close to the order of 40%. Moreover, since the data set includes prices up to the end of 2010, the worldwide credit crisis of 2008 along with the turning of Greece to the International Monetary Fund in 2009 are covered.

To examine the efficiency of ASE not only in isolation but mostly with respect to its size relative to other exchanges, we opted for using the whole set of data to concentrate on the average efficiency of the ASE for all these transitional phases.

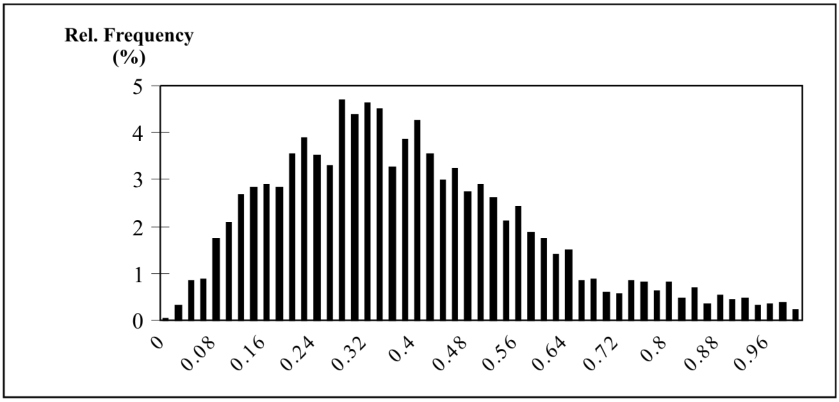
The ADU fractions were created taking into account all stocks listed or introduced in ASE for the abovementioned data set period. To avoid survivorship bias, data for stocks that were delisted before December 31, 2010 were also taken into account but only before the date these stocks were delisted. All data are available upon request from the author. Also, the Exchange Traded Funds introduced in ASE lately were excluded from this study.

In order to evaluate the power of predictions provided by (1) we computed the average information inaccuracy for 180 different values of N ($N = 1, ..., 180$) and 51 different values of a (from 0 to 1.00 with step 0.02). Then, for each N, we located the a minimizing the average information inaccuracy (hereafter denoted by: a^*). For a fair comparison of the projection methods given by (1) across the various N's the information inaccuracy of the first 199 trading days of our sample are excluded from the computation of $\overline{I(q:p)}$ and a^* so, all projection formulas are applied to the same set of 3,797 trading days.

3. Results

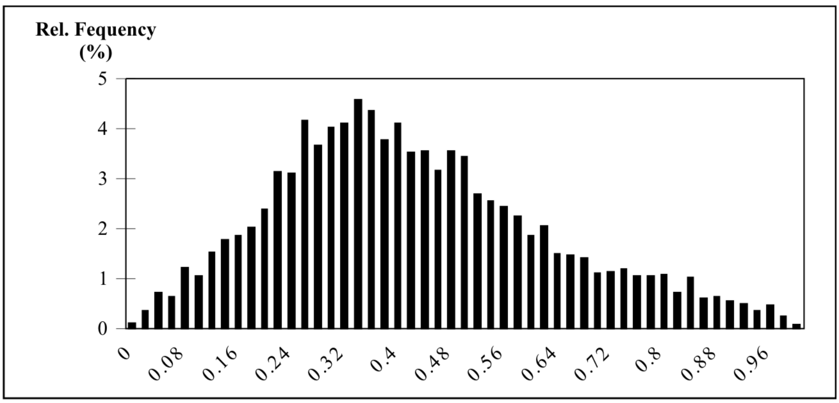
Figures 1, 2 and 3 present the relative frequency distributions for the ADU fractions respectively. Two interesting notes can be deduced from these figures. First, the findings of other researchers about the long term average of the ADU fractions is remarkably close to that of the Greek stock market: On average, 40% of traded issues advance each day, 40% decline and 20% remain unchanged. Second, the relative frequency distribution for the remaining unchanged issues proportion shows significant positive skewness (as measured by the third standardized moment) and

Figure 1. Relative frequency distribution for the proportion of advancing issues.



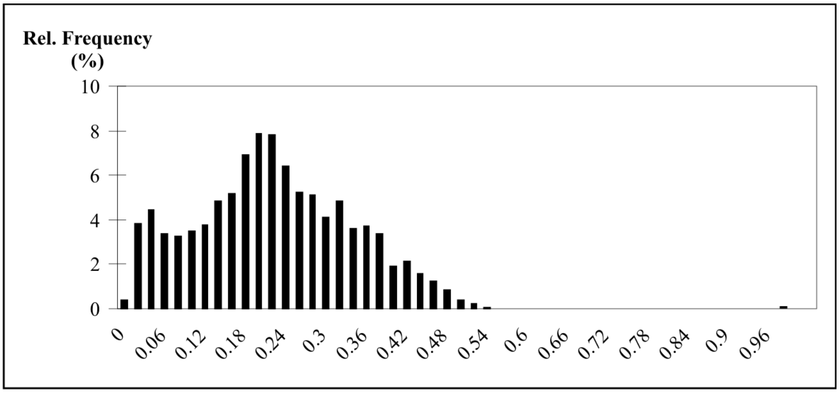
The arithmetic mean is 0.37299804, the standard deviation is 0.201757402 and the coefficient of variation is 54.09%. The third standardized moment is 0.706850177.

Figure 2. Relative frequency distribution for proportion of declining issues.



The arithmetic mean is 0.413767565, the standard deviation is 0.204036359 and the coefficient of variation is 49.31%. The third standardized moment is 0.497166673.

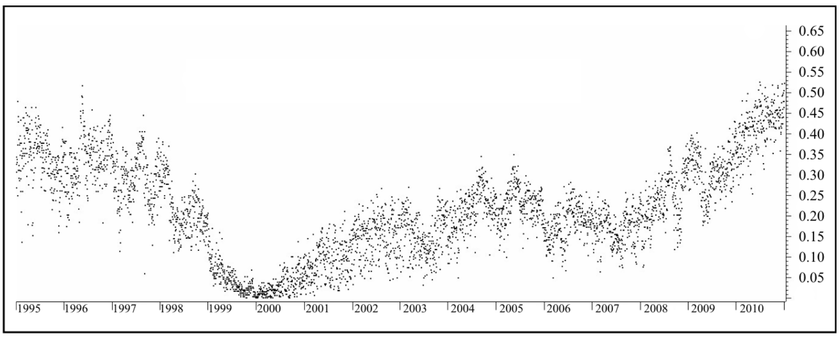
Figure 3. Relative frequency distribution for proportion of remaining unchanged issues.



The arithmetic mean is 0.213234395, the standard deviation is 0.115884 and the coefficient of variation is 56.50%. The third standardized moment is 0.407719609.

large coefficient of variation which was not the case for the larger exchanges of Amsterdam and New York. One possible explanation for this is the fact that our sample includes the vast "bullish" market of 1999 and the severe decline that followed. During that period, the publicity of the stock market and the volume of transactions were so high that it was difficult to find inactive stocks. (see figure 4).

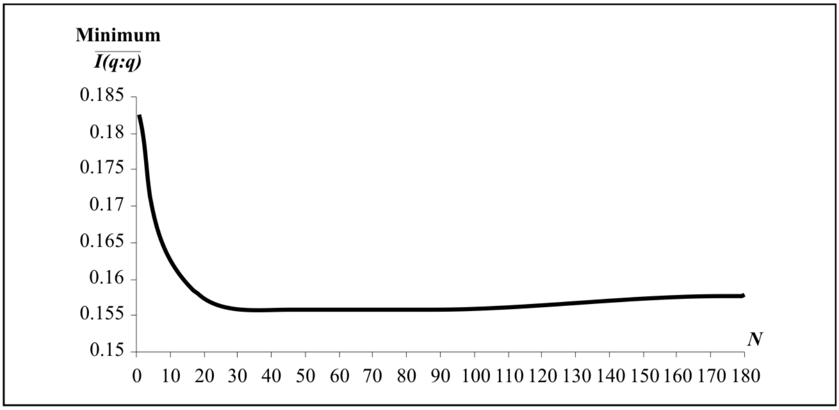
Figure 4. Portion of remaining unchanged issues in the ASE.



The portion of the remaining unchanged stocks during 1999 and 2001 is extremely low when compared to the same portion of the other years.

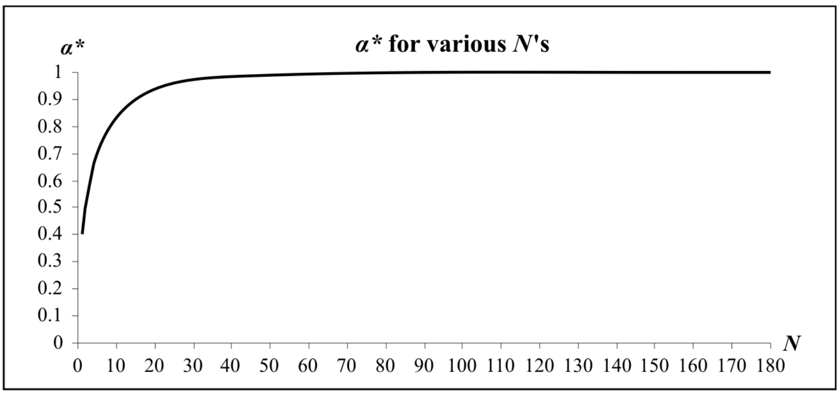
With respect to the efficiency of the prediction scheme of (3) the results are presented in figures 5 and 6. The overall minimum value of $\overline{I(q:p)}$ is 0.15577236 and it is attained when $N = 75$. This minimum value of $\overline{I(q:p)}$ is approximately 26.84% lower than 0.212922231 which is the average information inaccuracy found for the case $a = 0$. What is absolutely striking however is that the corresponding a^* for the case $N = 75$ is 1 which shows that the Greek stock market relies almost exclusively in a memory of 75 days.

Figure 5. Minimum average inaccuracy for various N's.



The vertical axis contains the minimum average information inaccuracy $\overline{I(q:p)}$ attained for each corresponding N of the horizontal axis when a ranges from 0 to 1.00 with step 0.02.

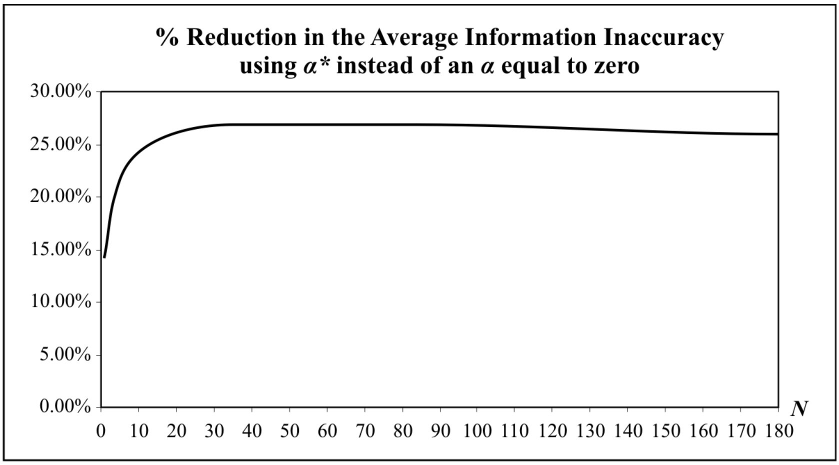
Figure 6. Corresponding values of a^* for various N's.



The vertical axis contains the a which minimizes the average information inaccuracy (namely: a^*) for each corresponding N of the horizontal axis.

It is apparent from figures 5 and 6 that as advances from 1 to 30, the corresponding a^* advances sharply from 0.4 to 0.96 and the corresponding $\overline{I(q:p)}$ declines steeply from 0.18260456 to 0.15586539. For values of N between 30 and 90 the $\overline{I(q:p)}$ ranges between 0.15577236 (when $N = 75$) and 0.15586539 (when $N = 30$) and for values of N greater than 90 $\overline{I(q:p)}$ advances indicating that more than 90 days of history do not contribute much to better predictions by (3) but they add small noise instead. It is furthermore notable that the prediction scheme for $N = 30$ gives a corresponding a^* of 0.96 and an impressive reduction of 26,8% in the average information inaccuracy over the case $a = 0$ (figure 7) which means that the effectiveness of the prediction scheme is based on the 30 most recent historical trading days.

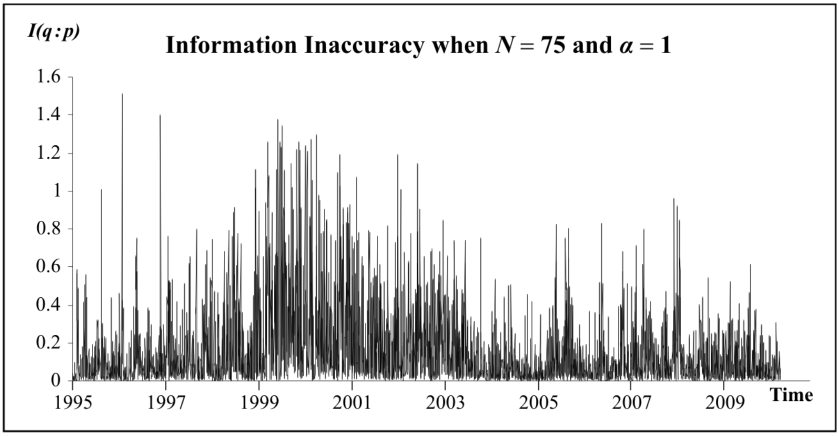
Figure 7. % Reduction in information inaccuracy using a^*.



The prediction scheme for $N = 30$ gives a corresponding a^* of 0.96 and an impressive reduction of 26,8% in the average information inaccuracy over the case $a = 0$.

It is also interesting to see how the information inaccuracy is distributed with respect to time for the case $N = 75$ and $a = 1$ which produces the minimum $\overline{I(q:p)}$ for all cases of N and a. In figure 8, the time series of information inaccuracy is presented. The standard deviation of $I(q:p)$ is 0.208033145 and the coefficient of variation is quite high: 133.55%.

Figure 8. Time series of $I(q:p)$ for the optimal case ($N = 75$ and $a = 1$).



The average information inaccuracy is 0.155772365 with a standard deviation of 0.208033145 and a high coefficient of variation of 133.55%.

4. Conclusion

The results of the present paper advocate on a less efficient Greek Stock Market in comparison to bigger and more mature markets. Amongst the stock exchanges of New York, Amsterdam, Greece and those of the Far East, the Greek market shows significantly less efficiency with respect to the proportions of advancing, declining and remaining unchanged issues. The Athens stock exchange was found to exhibit a very strong 75-day memory for these proportions in contrast to the other markets which exhibit at best a weak one day memory. The simple prediction formula (1) with $N = 75$ and $a = 1$ reduces the average information inaccuracy of the long average prediction scheme by 26.84% which is the highest among all reported reductions for the other markets. Moreover, a reliance of 96% in a 30-day memory is sufficient enough to improve the average information inaccuracy by an impressive 26,8% . The findings of this paper therefore support the thesis of Hi Hong that the size and matureness of a market is indissolubly connected to its efficiency (see also Jussi (2003)).

From a practical perspective, it should be noted that knowledge of the ADU fractions provides an immediate way to improve investment decisions in probabilistic terms. Since the simple front-weighted prediction scheme examined in this paper was found to be of value, there is evidence that the ADU fractions show trend characteristics in the Greek stock market and this could spark further research to examine more complex algorithmic prediction schemes for them based mainly on a moving time window of 30 to 90 trading days.

It is important to note that the analysis conducted in the present paper was based upon a whole 15 year time span covering significant periods of the Greek stock market. It would be of interest to check the coherency of the results during different smaller time periods each one covering a specific economic phase. Furthermore, it should also be stressed that all stocks of the ASE was taken into account in our study. Of profound practical interest would be to examine whether promising prediction schemes exist for fractions of advancing, declining and remaining unchanged issues within specific market sectors or to define what an advancing, declining and remaining unchanged sector could be and then study the associate fractions.

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