How noise trading affects the Chinese stock market: An evolutionary game theory approach

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Abstract

This paper investigates the Chinese stock market with regard to noise trading behaviour and its impact on the Chinese stock market. Applying evolutionary game theory as the methodology, different features of noise traders and information traders are analysed. With bounded rationality and profit maximisation characteristics, the evolutionary game theory and the replicator dynamics equation are applied with secondary data from the Chinese stock market for investigating its evolutionary process. The result shows that not only does noise trading behaviour affect the stock prices, when the proportion of noise traders is large, it also drives the stock market to a very risky position. Finally, this research examined how noise trading behaviour and the related evolutionary process are involved in different market situations. As a result, the study shows that the current Chinese stock market is in a very risky situation. In the meantime, the stock market is evolving to an equilibrium that is tending towards the noise trading position, which is driving the current Chinese stock prices away from the real values. Moreover, stock trading is very much based on noise rather than information. Thus the stock market will be dominated by noise trading unless the environment changes.

Keywords: Noise trading, evolutionary game theory, replicator dynamics

Introduction

The Chinese economy is booming significantly since the switching from a centrally planned economy (CPE). The stock market has benefited from enormous growth from the market-oriented economy since its reappearance in the 1980s. China's stock market has grown from stagnant in the middle of 2006 to a stable uptrend in recent years. The reasons behind the scene can be countless. Fundamental factors decide the market's fluctuation such as firms' values, P/E ratios, inflation rate and interest rate etc. However, another major issue that influences the stock market, especially the Chinese stock market, is the behaviour of the market subjects (the investors). In terms of the effective allocation of the market resources, the investors' investment behaviour plays an important role.

When considering the Chinese stock market, compared to western markets, the availability of information, and the analysis of buyers and sellers are rather poor. Furthermore, apart from some large state-owned firms or a few well-established companies, most of the public companies do not have sufficient information of their track record. A wise risk-averse investor like Buffett who outperforms the market will not hold such stocks in the long-run, or will not even be interested in this kind of stocks. Thus, to study the Chinese stock market, although technical and fundamental analysis is applied in this paper, it is not the main method by which to generate the investment behaviour strategy. Instead, the evolutionary game theory approach is considered appropriate and will be discussed in the methodology section. Thus the main focus of this paper is to apply the evolutionary game theory and consider the facts in terms of behavioural finance theory, to study the investment behaviour of the China stock market and its evolutionary outcomes.

Traditional theories of analysing investment decisions such as Modern Portfolio Theory (MPT) and Capital Asset Pricing Model (CAPM) are based on certain assumptions: investors are rational, and pursue the highest expected returns. These theories use rigorous application of mathematics, and allocate investment behaviour in the direction of optimal results.

One of the reasonable assumptions is rationality. A rational investor is believed to be profit-driven and has the ability to adjust amongst different information

received. However, recent studies have argued that the Efficient Market Hypothesis and the rationality of investors are defective. Investors of a stock market are quite different from traditional financial individuals or groups. The educational levels, age group, regional and cultural backgrounds vary enormously. Thus they respond differently and tend to be unpredictable based on unexpected circumstances, such as, misjudgement of information, overconfidence from holding an overvalued stock, and so on (Lease, Lewellenand Schlarbaum, 1974).

If the proportion of this kind of investor or investment behaviour tends to increase or holds for a significant level and period, it will influence and drive the market to an unexpected position. However we cannot say this factor is significant before determining the market. If we consider the Chinese stock market, which originated in the late 1980s, it is still young and has a lot to learn from the more developed western markets. Inefficiency and noise level are relatively higher than the western stock markets. As we will discuss and analyse later in this paper, the stock turnover rate of Shanghai and Shenzhen is much higher than the New York Stock Exchange market (NYSE), and even higher than the Tokyo Stock Exchange (TSE). Furthermore, the beta of the Chinese stock was found to be very unstable and it poorly measured the volatility of the market. Thus the unstable market character and high level of noise trading make the Chinese stock system risky and speculative. With the evolution and growth of the stock market, all the underlining threats and risks will be exemplified. Thus, the participants and consumers of a stock market suggest investors' behaviour has a great influence on the market, and the study of this behaviour, especially its evolution mechanism, is quite valuable.

This paper outlines the significance of noise trading and its impact on the recent China stock market. After a particular discussion of the recent Chinese stock market's characteristic, the basic concept of Evolutionary Game Theory and its practical application is introduced. A model is set up with relative market data to help analyse the market's evolutionary outcome, then conclusions and recommendations are generated to help understand the Chinese stock market's moving trend and its possible evolutionary equilibrium.

Literature review

Noise trading

Previous studies showed that investors sometimes do not follow economic principles when evaluating a certain asset or the market portfolio. Individual investors are more likely to invest in a small number of different assets, thus diversification is hardly achieved. Lease, Lewellen, and Schlarbaum, (1974) indicated that investors typically hold a single stock instead of diversifying. However not all the investors have the ability to analyse the market using appropriate financial and mathematical tools; they tend to choose stocks based on their own study – self-calculation, self-research or information from neighbours. Black (1986) defined these kinds of investors who have no inside information accessibility, and irrationally act on noise as if it were information that would give them an edge, as noise traders.

Black (1986) further indicated that people usually trade on information and it is correct to extract profile from these trades, but sometimes people trade on noise rather than information, and it is not correct to use the profile from these trades. Delong, Shleifer, Summer and Waldmann (1990) shared this point of view by indicating that if noise traders irrationally believe that they have accessibility for the information of a specific asset and profile signed by stockbrokers, economic consultants or their technical analysts, they irrationally believe these signals carry information rather than noise. By applying this "information" into their portfolio and investment strategies, it will cause significant loss especially in the long run. Even worse, if this behaviour is exhibited in an experimental manner, it influences the market. For instance, when the stock market is filled with a great proportion of noise traders, trades based on noise will drive the stock value away from its actual value (fundamental value). Additionally, sometimes even when stock prices are out of sync from their actual value, rational strategy may not earn a profit, which means that a rational strategy may fail in an irrational market. Therefore, there is another problem faced by rational investors: will information (rational) investors or strategies still be rational when they are faced with different proportions of noise traders in the market? Alternatively, will the definition of rationality in stock market need to be redefined? In a stock market, there are different kinds of investors who believe in various strategies. Sometimes they

perform rationally, while sometimes they perform irrationally. In other words, sometimes they choose rational strategies while sometimes they choose to trade on noise, intentionally or unintentionally.

Hence, for a wise investor, taking other investors' behaviours into account, with regard to their decisions about the information before making their decisions could result in a better return. However, if this idea turns out to be common knowledge, other investors might accept it and change their investment strategy dynamically, and this change will and should also be accepted by the wise investor, who takes this strategic change into account and redefines his investment strategy. If this process is repeated over and over, the stock market will be a game field where investors with different behaviours compete. Moreover, for different stock markets, the characteristic is also different. For example, the Chinese stock market's noise trading level could be higher than the mature European markets or US market. Moreover, for the market itself, the rational investment strategy and irrational investment strategy coexist in varying proportions (Black, 1986). Consequently the change in the market is the dynamically proportional changes of these two kinds of investment strategies over different periods.

China's stock market

The Chinese stock market, during its short period of growing over the last few decades, has finished its full evolutionary cycle of boom and bust. Until 2000, the Chinese stock market's capitalisation reached its booming point of 4.8 trillion RMB. This equalled half of the GDP and one fourth of the nation's financial assets at that time. However, the later movement of the market capitalisation was surprisingly dropped to 3.7 trillion RMB, which only represented 25 percent of GDP at that period (Riedel, Jin & Gao, 2007).

The bull and bear market characteristics during the last two decades are decided by the following factors.

The growing number of public listed companies and investors since the 1990s made the Chinese stock market a great source of funding for firms. According to Riedel et al (2007), from 1995 to 2001, the number of listed companies rose

nearly fourfold (from 300 to 1,100). Furthermore, according to Zhang's (2004) study, most of the published firms were state-owned companies (80 per cent), which have stronger accessibility to bank credit and bond. However, the 1990s stock market of China did not really represent the nation's economy at that time.

The other factor that reflects the Chinese stock market character is the short-term trading. Still in the late 1990s, the returns of short-term investment of A-shares were the highest in the world (Riedel et al, 2007). For the same period, the turnover rate of the Chinese A-shares was also very high. Most of the investment was not going to last more than two months for that period, comparing to 18 months hold time in the American stock market (Riedel et al, 2007). It makes sense when investors buy a stock one day, and get a lot of money when they sell it the next day. Thus, to hold a stock as a long-term investment seems to be a riskier strategy in this particular situation. This gambling investment behaviour surrounding the Chinese stock market especially for that period made the investment environment noisy and risky. This also makes sense from an economic point of view: for whatever reasons, when the demand of a product (stock) is increasing, the price of the product will increase fundamentally. However, the sad part is that the stock price represents the company's performance weakly. This is very risky when investors do not have the confidence of investment, the stock prices will turn to bearish even if the firms are performing well. What is needed is just an inside incidence.

In 2001, caused by the market downturn driven by the collapse of the US security market, plus the previous influence of the 1997-8 Asian financial crisis, the Chinese stock market started to fall. We can hardly say that these were the main reasons that changed the Chinese stock market to the opposite direction. However these incidences did make investors realise that they might be overconfident. As a result, since a great proportion of the investors were expecting a negative return over the market, one man's force will not change much. Because this is much more than just investments, it is a game.

In the Chinese stock market, noise is the information that is not reflected in a value unrelated to the actual stock value, but it influences the investment

behaviour and consequently the market. It can be arbitrarily made by the market participants or by misjudgements. Moreover and specifically for the less efficient Chinese stock market, noise should also include the technical experience of the individual investors.

Shiller (1990) proposed that investors are bounded rational (even irrational), and their investment behaviour is represented as irrational. Delong, Shleifer, Summers and Waldmann (1990) also described that many investors do not follow the economics rules when making market portfolio decisions. They indicate that individual investors typically fail to diversify but just hold a single stock (or a small number of stocks) and choose stocks based on their own research and their investment behaviours tend to be frequently influenced by each other. They believe that under incomplete information, noise traders make poor predictions about the future price and lead the security's price to deviate from its accrual value. The influence of noise traders may exist in the long-run or affect the market significantly.

As the history of the Chinese stock market is short, and its participants' investment behaviour and experience are relatively immature, noise trading is significant in the market. Therefore the study of investment behaviour and its evolutionary pattern is important.

This paper develops a model based on these questions by using theory and market analysis rather than trying to cover every issue. So it is not necessary to analyse every specific stock thoroughly. Thus to take the Chinese stock market as a whole and further the investigation through tracking stocks overall is sufficient, as stock trading information (trading history, price and volume etc.) is purely and perfectly presented, and is gathered as the main data of this study. The time horizon of this study should be longitudinal (Sekaran, 2003) because further analysis might be wanted for future comparisons. Secondary data will be collected based on the existing research (books, journal, internet etc.) and historical data analysis such as interest rates, stock trading data and figures will be performed by applying correlative financial tools. To set up the analytical equation, the replicator dynamics analysis and the stability theorem are applied, to find out the expected evolutionarily stable strategy (ESS).

Methodology and data collection

To solve the problem and testify the results, the evolutionary game model is applied. To set up the analytical equation, the replicator dynamics analysis and the stability theorem are applied, to find out the expected evolutionarily stable strategy (ESS).

The application of differential coefficient is used for finding equilibrium point(s), followed by linear graphs as the analysis tool to represent the market moving (evolution) trend. Next for the data retrieved from the stock market, which includes stock prices and variables, average interest rates as secondary data are gathered and represented by calculation with tools such as Excel and financial modelling. Finally other areas of data analysis involve variance and covariance analysis, functions and equation setup.

The data of this paper is for the period starting from 2004 to the beginning of 2009 and from the Shanghai Stock Exchange market's monthly developed data which is from over 862 public firms. This data is used to generate the practical evolutionary character of the Chinese stock investment behaviour. The data sources are mainly from the Yahoo Finance (n.d.), Bank of China (n.d.), and Shanghai Stock Exchange (n.d.) databases. The quoted five years average annual deposit rate is the interest rate used during the period of the study. The calculations of stock return variance and turnover rates are based on publicly released data from the Yahoo Finance (n.d.) site and the Shanghai Stock Exchange (n.d.) database.

All data collected are historical secondary data. In terms of generating the dynamic process of stock investment behaviour, the learning and evolution process is based on investors' strategic performance. Thus, the backtracking of historical performance can help the researchers find current market status and uncover future implications.

Evolutionary game theory

The original idea of Evolutionary Game Theory (EGT) was raised by John Maynard Smith and George R. Price. It was previously used in a biological

context as indicated in the title of Smith and Price's study: "The Logic of Animal Conflict" (Smith & Price, 1973). Survival adaptation behaviour implies that animals will choose to increase their ability and reduce the probability of fight as their best strategy. Further as this strategy spreads in the population, it turns out to be the best evolutionary strategy until evolutionary stability is reached.

According to Gardner (1995), there are two methods to study EGT. The one applied in this paper is Replicator Dynamics. Here, we have to reiterate the bounded rational concept. When a bounded rational player plays a game, he or she makes mistakes and errors occur during judging among the different strategies. So under these circumstances, players have to learn and improve. This trial-and-error activity is called replicator dynamics (Gardner, 1995).

Mathematically, replicator dynamics and the replicator equation explains the situation in the population. When a strategy can provide an above average return, then the proportion of this strategy increases. On the other hand, when the strategy brings a below average payoff, then that strategy's proportion decreases in that population. The replicator equation (Gardner, 1995) used to study EGT and applied in this paper is:

$$dx/dt = x[u_x - u_{avg}]$$

x is the percentage of players choosing strategy *i*, denoted by Si, or the percentage of chance to choose Si by a single player.
u is the related payoff (return).
u_{avg} is the average returns.
So, dx/dt is the rate of change of x's percentage.

The Evolutionary Game Equilibrium occurs when dx/dt=0 at which point a minor change in terms of x's percentage will not bring a change in the value of dx/dt. When the dx/dt=0 condition is satisfied, the x value at this point(s) can be found after we prove that x is the only variable of the equation dx/dt that is dx/dt = F(x) =0. However, before we address this (these) x value(s) of the evolutionary

stable strategy, the researcher will introduce the Stability Theorem (Gardner, 1995) which will be discussed further in this study.

Model setup

In the Chinese stock market, let x be the percentage of investors as noise traders whose choice strategy is not rational. Then, the proportion of rational investors in the market population is 1-x. Let u_n be the return for noise trading, and u_i be the return for information trading.

To apply the replicator equation:

$$\frac{dx}{dt} = x[u_x - u_{avg}]$$

We get,

$$\frac{dx}{dt} = x[u_n - u_{avg}]$$

Since $u_{avg}=x*u_n+(1-x)*u_i$, we apply to the above equation to get:

$$\frac{dx}{dt} = x(1-x)(u_n - u_i)$$

According to Delong et al's (1990) noise trading function, the investor payoff function is:

$u = -e^{-(2\gamma)w}$ (1)

$u = e^{(2\gamma)w}$ (2)

Function (1) is the rational investor payoff function; function (2) represents the noise trader payoff. To maximise (1) and (2) is equivalent to maximising the below functions respectively:

$E(u_i) = \bar{w} - \gamma_i \emptyset^2$ (3)

$E(u_n) = \bar{w} + \gamma_n \emptyset^2$ (4)

While, $\bar{w}$ is the expected final payoff, $\emptyset_w^2$ is the variance of the expected payoff, γ is the coefficient number (Delong et al, 1990).

To apply Delong's replicator function:

$$f(x) = \frac{dx}{dt} = x(1-x)\{\frac{Z}{2\emptyset^2(1-\tau)[\gamma_n-(\gamma_n+\gamma_i)x]^2}\} \quad (5)$$

Where, $Z=ax^2+bx+c$, τ is the percentage of the transaction cost.

To find the first derivation of Z, then get:

$$f(x) = \frac{dx}{dt} = x(1-x)\{\frac{ax+b}{2\emptyset^2(1-\tau)[\gamma_n-(\gamma_n+\gamma_i)x]^2}\} \quad (6)$$

According to Stability Theorem:
To let f(x) =dx/dt=0, there are two or three equilibrium points

x=0, x=1 and x= - b/a

x=0, 1 are the two existing equilibrium points; whether or not the third equilibrium point exists (x= - b/a) depends on the value of –b/a. If it locates between the interval [0, 1], then it is an equilibrium. If not, then there are only two equilibriums (0 and 1).

According to Delong et al (1990),

$$A = -\frac{8\gamma^3\emptyset^4}{(1+r)^4} - \frac{4\gamma^2\emptyset^2(1-\tau)}{(1+r)^2} \quad (7)$$

$$B = -\frac{2\gamma^2\emptyset^2(1-\tau)}{(1+r)^2} - (1-\tau)^2\gamma(1+\emptyset^2) \quad (8)$$

From the above equations, it is clear that the value of (–b/a) depends on the values of coefficient numberγ, the interest rate during the period, transaction cost τ , and the variance$\emptyset$.

Results and analysis

Until end of 2008, the interest rate of one-year term deposit averaged 2.628% for the previous five years (from 2004).

Regarding Friend and Blume (1975), the value of the coefficient number γ should be greater than 2 in the real market. In the Chinese stock market, as the noise trading proportion is higher than other mature markets, it suggests that more investors are likely to invest in a risky situation. Therefore, the assumed γ value is the minimum value 2.

The average of 862 stocks' turnover rate is 515%, which means that the average period for an investor to hold a single stock is about 2.5 months. The variance for the period of the market risk is 4.13%.

Transaction cost τ is 0.3% (Shanghai Stock Exchange, 2008)

Considering the replicator equation,

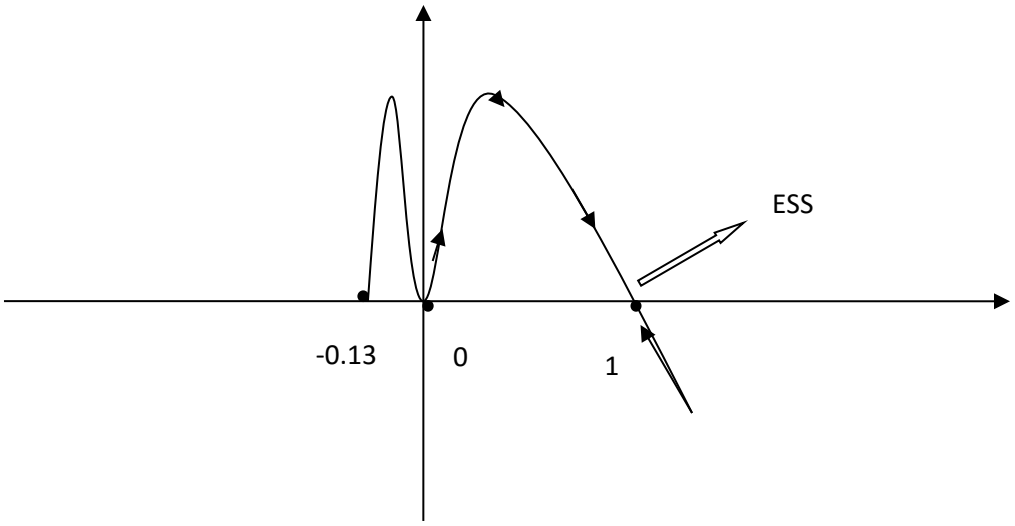
$$f(x) = \frac{dx}{dt} = x(1-x)\{\frac{Ax+B}{2\emptyset^2(1-\tau)[\gamma_n-(\gamma_n+\gamma_i)x]^2}\} \quad (6)$$

To apply the above discussed equations, then we get the value of –b/a= -0.1323<0.

Then, from the replicator equation and the previous analysis, (x= -b/a) is not in the interval [0, 1]. Considering the equation (6) and the stability theorem that was explained previously, the two roots of the function are x=0 and x=1. In addition, x=1 is the evolutionarily stable strategy. That is, the noise-trading proportion will evolutionarily reach 100% and dominate the market. Moreover, any system mistakes for the short-run will not change the market stability.

Figure 1 below shows the current Chinese stock market evolutionary dynamics.

Figure 1: Chinese stock market evolutionary dynamics



Implications

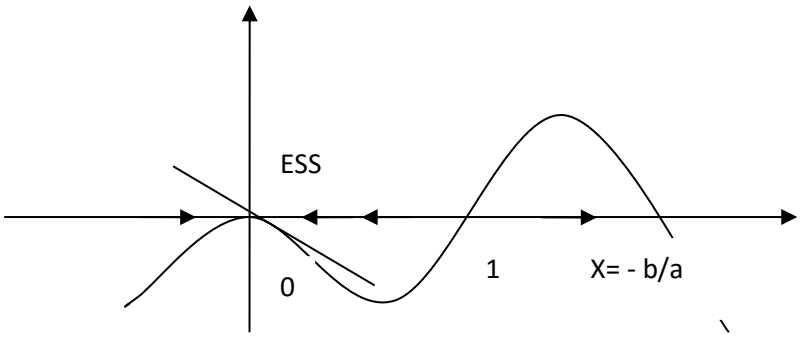
As the result shows, the current Chinese stock market's fluctuation is relative to the investment noise trading behaviour. Because the investors are considering the optimistic side of the market returns, they are continuously entering the market and pushing the price to a level that much more than its real value. This is occurring, because investors want to gain a higher profit that is based on a rather high risk. This will attract more and more investors to join this high-risk preference group so there is more noise trading in the market that could occur. As a result, increasing the bubble phenomenon possibility will let the noise traders dominate the market.

It is very clear that the outcome of the stock investment gaming behaviour is influenced by which game evolves and is decided by the value of –b/a. This study analysed the current Chinese stock market and shows it is evolving towards noise trading equilibrium (the Evolutionarily Stable Strategy). However, as the circumstances change and the maturity of the Chinese stock market develops, the equilibrium might change and reach another position. Currently the status is decided by certain market characteristics, such as the market return variance (Φ), the interest rate (r) and most importantly the current expectation of returns foreseen by investors. These factors are not fixed,

and it is possibly changing in the future. It is hard to calculate the future evolution of human behaviour, but it is possible to illustrate the possible outcomes when circumstances change.

The graph below (Figure 2) illustrates the other evolution process of the Chinese stock market based on a different –b/a value. The analysis of this situation can be explained as below. It is possible to occur after the current Chinese stock market reaches the situation showed in Figure 2.

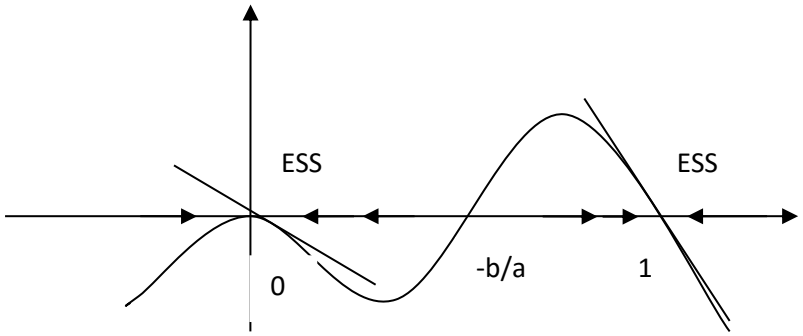
Figure 2: Another evolution process



Considering the situation of the above graph, if the variables' changed results are in the third value of $x > 1$ (proportion of noise traders). We can apply the Stability Theorem, to get the evolutionarily stable equilibrium where $x=0$ (which satisfies $f(x) =0$, and $df(x)/dx<0$). This situation explains that the proportion of noise traders is evolving to a stable point of zero percent, and the strategy of information trading will dominate the stock market. Therefore, stock prices will closely represent the real value of stocks. Stock trades based on information then will gain more profit than from noise trading. Risk-averse investors tend towards this market situation.

Figure 3 below shows the situation that the third root of the x value is between interval [0, 1].

Figure 3: The third root of the x value is between interval [0, 1]



In this situation, when the third value of x (-b/a) is in between the interval [0, 1], then there are three equilibriums. Moreover, two of them satisfy the ESS condition (x=0, 1). The stock evolution process can converge to the stable equilibrium of risk-averse (when x=0) or the risk-preference equilibrium (when x=1). From the graph, the possibilities of reaching the equilibrium of 0 and 1 are values of –b/a, 1+b/a (in this situation, -b/a is a positive number, which satisfies –b/a>0, and 0<1+b/a<1 as shown in Figure 3) respectively.

Alternatively, mathematically speaking, there will be (–b/a) percentage of the population (investors), who tend to choose the risk-averse strategy and (1+b/a) percentage of the population, who tend to prefer risky investments even if the strategy is based on noise.

Limitation of the model and result

The model is based on certain assumptions, while a more practical evolvement is to induct a different set of stock portfolios to represent the possibility of investment strategies for the various risky assets. However, to generate the representative sets of portfolios with random matches for nearly 1,000 stocks is not practical. So a good computer programming application will help compute this model to get a better result.

Secondly, the model can only tell where the evolution process is going, and to which point the game will be at an equilibrium. However, it cannot figure out how long the process takes. In the real world, it took the ancestors of frogs 300

million years of evolution through natural selection to evolve ears and their calling behaviour (Gardner, 1995). However, it only took decades for Nintendo to start from a card and toy producer to today's Wii technology. To determine today's stock market of China, is probably an equilibrium that is difficult to achieve.

Conclusions and recommendations

Noise trading behaviour is commonly seen in security markets. However, when noise traders are proportionally high in the current Chinese stock market, the stock prices do not represent their real values but are affected by risk noise. The value of a risky asset contains information such as the firm's value, the products produced, the industry's characteristics, and so on. In the stock market, the demand and supply of stocks also influence their prices' fluctuation. Such factors represent the stock values in a reasonable manner and can be technically analysed. However, when investment behaviour is very much driven by irrational noise, the circumstance can hardly be evaluated and causes the market to move to a risky and unstable situation. This is very risky especially when the market is not mature such as the Chinese stock market.

Although stock investment is risky, this situation is not reliable and enlarges the speculative bubble. Thus, this circumstance forces the rational investors to act irrationally, and this is the current situation of the Chinese stock market: if investors want to survive in the current Chinese stock market, then they must act irrationally.

Two recommendations might be practical from the researcher's point of view. First, the investors should readjust their investment behaviour to accommodate a long-run attitude. Stock investment is not gambling, therefore trading on noises is creating higher risk, but it does not always provide higher returns. Second, for the government's regulatory body, it is their responsibility to provide and develop a more efficient security exchange platform that can enhance and filter the market information. Therefore to reduce the spread of noises is essential for a more efficient platform.

The Chinese stock market is growing at an enormous rate. However, the driver behind the growth is what finance professional and investors need to be aware of. The maturity of a stock market not only brings greater wealth, but also it can deal with unexpected situations created by noise. The more stable and mature a system is, the better it can deal with both the positive and the negative situations which arise.

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