ABSTRACT. Recent progress of computer technology makes it possible to analyze financial and economic systems through simulation studies. Among them, agent-based modeling is promising. In this paper, using agent-based modeling from distributed artificial intelligence, I discuss the validity of passive investment strategies in financial markets where active investors who hold future information exist. As a result of intensive experiments, I made the following findings: (1) active investing could get positive excess return from the short-term viewpoint; (2) passive investing, as is consistent with traditional financial theory, is valid even when the introduction of active investors holding future information. These results contribute to clarifying the mechanism of price fluctuations in financial markets and are notable from both academic and practical viewpoints.

INTRODUCTION

The role of asset management has become critical because of the rapid globalization of financial markets and the rigidity of economic systems. So far, a growing body of argument has been discussed to understand the mechanisms of the asset price fluctuations and various kinds of investment methods including the techniques in financial engineering have been proposed for dealing with the financial markets (Markowitz, 1952; Black and Sholes, 1973; Ingersoll, 1987, Luenberger, 1997).

In asset management business, although many kinds of investment strategies have been proposed, active management is the predominant model for investment strategy today. Active management is an attempt to find "good deals" in the financial markets, and they allocate assets based upon empirical research delineating probable asset class risks and returns within and across asset classes. Their objective is to make a profit better than they would have done if they simply accepted average market returns. However, they sometimes fail because of unpredictable phenomena in the financial markets.

On the other hand, making no attempt to distinguish attractive from unattractive securities, passive investment tries to keep average performance using Benchmarks based on market indices (Malkiel, 2003). They invest their asset in company's stock in proportion to market weight and maintain it throughout investment periods. The efficiency of the market is the central hypothesis in the world of traditional financial theory (Sharpe, 1964; Fama, 1970). Since it is very difficult for investors to get excess return in an efficient market, passive investment strategy is considered to be an effective investment method.

Recently, however, traditional financial theories have been criticized. Questions have arisen over their explanatory power and the validity of their assumptions (Kahneman and Tversky, 1979, Tversky and Kahneman, 1992). For example, behavioral finance has recently been in the limelight and many reports indicate that deviation from rational decision-making can explain anomalies which cannot be explained by traditional financial theories (Shleifer, 2000; Shiller, 2000). Moreover, there are many analyses which point out the drawbacks of traditional financial theory from the view points of information structures, financial restrictions and so on (Brunnermeier, 2001). There is a growing need for analyses which take realistic aspects of financial markets into account.

Generally, analyses which take realistic aspects into account are more complicated compared to the models proposed in traditional financial theory. For
example, the simple and rational behavior which traditional financial theory assumes and expects from investors is challenged by behavioral financial theory. Behavioral financial theory proposes a far more complex decision-making process, where human error, misinterpretation and false pattern recognition, for example, are taken into account. For this reason, behavioral financial analyses often encounter difficulties in determining asset prices (Axtell, 2000). In order to develop analyses capable of capturing several important aspects of real financial markets, we need to develop a different analytical method.

In the area of computer science (Russel and Norvig, 1995), agent-based modeling has been proposed as an effective approach to analyze the relationship between micro rules and macro behavior (Epstein and Axtell, 1996; Gilbert, 2007). This is a bottom-up approach that tries to describe macro behavior of the entire system using local rules (Axelrod, 1997; Takahashi, 2011; Tesfatsion, 2002). This approach is appropriate for analyzing a multi-agent system in which a great number of agents, acting autonomously, are gathered together in one market. The agent-based approach has been applied to a wide range of academic disciplines, such as engineering and biology, and many reports have been made about analyses adopting this approach in the field of social sciences (Arthur et al., 1997; Levy et al., 2000; Lux et al., 1999; Takahashi and Terano, 2007a; Takahashi, 2010).

With this background in mind, the purpose of this research is to analyze the market where realistic financial conditions, such as various types of investors, are taken into account. This research attempts to clarify the validity of passive investment strategies in financial markets where active investors who hold future information (hereinafter informed trader) exist. Our simulation model is characterized by 1) fundamentalist, informed trader and non-fundamentalist agents with decision making strategies about trading the assets of either individual stock or riskless assets; 2) an artificial market, in which the profits will occur based on the Brownian motion, and each agent trades its asset based on its profits and past pricing information (Takahashi and Terano, 2003). The contributions of the paper include to show the effectiveness of agent-based modeling to analyze the validity of investment strategies from micro-macro links through the modeling methodology.

MODEL

A computer simulation of the financial market involving 1000 investors was used as the model for this research (Fig. 1). Shares and risk-free assets were the two types of assets used, along with the possible transaction methods. Several types of investors exist in the market, each undertaking transactions based on their own stock evaluations. This market was composed in three major stages; (1) generation of corporate earnings, (2) formation of investor forecasts, and (3) setting transaction prices. The market advances through repetition of these stages (Takahashi et al., 2003). The following sections describe negotiable transaction assets, modeling of investor behavior, transaction price setting, and rules of natural selection in the market.

Fig.1. Basic architecture of financial market simulator.
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Negotiable Assets in the Market

This market has both risk-free and risk assets. There are risk assets in which all profits gained during each term are distributed to shareholders. Corporate earnings ($y_t$) are expressed as $y_t = y_{t-1} + (1+\epsilon_t)$. However, they are generated according to the process of $\epsilon_t \sim N(0, \sigma^2)$ with share trading being undertaken after the public announcement of profits for the term (O'Brien, 1988). Each investor is given common asset holdings at the start of the term with no limit placed on debit and credit transactions (1000 in risk-free assets and 1000 in stocks). Investors adopt the buy-and-hold method for the relevant portfolio as a benchmark to conduct decision-making by using a one-term model.

Modeling Investor Behavior

Each type of investor handled in this analysis is organized in Table 1. The investors can be classified into two categories: active investors (Type 1-5) and a single passive investor type (Type 6). Active investors in this market evaluate transaction prices based on their own forecasts of market movements, taking into consideration both risk and return rates when making decisions (Fig. 2). Passive investors employ a buy-and-hold strategy. Each active investor determines the investment ratio ($w_t^i$) based on the maximum objective function ($f(w_t^i)$), as shown below.

$$f(w_t^i) = \frac{1 \cdot c^{-1} \left( \sigma_{t-1}^i \right)^2 \cdot r_{t+1}^{f,i} + 1 \cdot \left( \sigma_{t-1}^i \right)^2 \cdot r_{t+1}^{m,i}}{(1 \cdot c^{-1} \left( \sigma_{t-1}^i \right)^2 + 1 \cdot \left( \sigma_{t-1}^i \right)^2)}$$

Here, $r_{t+1}^{f,i}, r_{t+1}^{m}$ expresses the expected rate of return, calculated from short-term expected rate of return, and risk and gross current price ratio of stocks respectively. $c$ is a coefficient that adjusts the dispersion level of the expected rate of return calculated from risk and gross current price ratio of stocks (Black and Litterman, 1992).

The short-term expected rate of return ($r_t^{f,i}$) is obtained where ($P_{t+1}^{f,i}, y_{t+1}^{f,i}$) is the equity price and profit forecast for term $t+1$ is estimated by the investor, as shown below.

$$r_t^{f,i} = \frac{\left( P_{t+1}^{f,i} + \frac{y_{t+1}^{f,i}}{P_t - 1} \right) \cdot (1+\eta_t)}{\left(1 + \frac{y_{t+1}^{f,i}}{P_t} \right)}$$

The short-term expected rate of return includes the error term ($\eta_t \sim N(0, \sigma^2)$) reflecting that even investors using the same forecast model vary slightly in their detailed outlook. This paper analyzes two cases where the dispersion of valuations is normal ($\sigma_n = 5\%$) and large ($\sigma_n = 10\%$). The stock price ($P_{t+1}^{f,i}$), profit forecast ($y_{t+1}^{f,i}$), and risk estimation methods are described in the following section.

The expected rate of return obtained from stock risk and so forth is calculated from stock risk ($\sigma_t^i$), benchmark equity stake ($W_{t-1}$), investors' degree of risk avoidance ($\lambda$), and risk-free rate ($r_f$), as shown below (Black and Litterman, 1992; Sharpe, 1987).

$$r_t^{im} = 2 \cdot \lambda \cdot \left( \sigma_{t-1}^i \right)^2 \cdot W_{t-1} + r_f$$

Fig. 2. Active investors’ behavior.
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Table 1. List of investor types

<table>
<thead>
<tr>
<th>No.</th>
<th>Investor types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fundamentalist</td>
</tr>
<tr>
<td>2</td>
<td>Informed trader</td>
</tr>
<tr>
<td>3</td>
<td>Forecasting by past average (most recent 10 days)</td>
</tr>
<tr>
<td>4</td>
<td>Forecasting by trend (most recent 10 days)</td>
</tr>
<tr>
<td>5</td>
<td>Latest Price</td>
</tr>
<tr>
<td>6</td>
<td>Passive investor</td>
</tr>
</tbody>
</table>

**Stock Price Forecasting Method.** The fundamental value is estimated by using the dividend discount model, which is a well-known model in the field of finance. Fundamentalists estimate the forecasted stock price and forecasted profit from the term \( y_t \) and the discount rate \( \delta \) as \( (P_{t+1}^i) = \gamma_t / \delta, \gamma^i_{t+1} = \gamma_t \). As for informed traders, they hold next step’s information, so they estimate the forecasted stock price and forecasted profit as \( (P_{t+1}^i) = \gamma_{t+1} / \delta, \gamma^i_{t+1} = \gamma_t \). Forecasting based on trends involves forecasting the next term stock prices and profit through extrapolation of the most recent stock value fluctuation trends. The next term stock price and profit is estimated from the most recent trends of stock price fluctuation \( (a_{t-1}) \) from time point \( t-1 \) as \( P_{t+1}^i = P_{t-1} \cdot (1 + \alpha_{t-1})^2, \gamma^i_{t+1} = \gamma_t \cdot (1 + a_{t-1}) \). Forecasting based on past averages involves estimating the next term stock prices and profit based on the most recent average stock value.

**Risk Estimation Method.** In this analysis, each investor estimates risk from past price fluctuations. Specifically, stock risk is estimated as \( \sigma^2_{t-1} = \sigma^2_{t-1} \) (common to each investor). Here, \( \sigma^2_{t-1} \) represents the stock volatility that is calculated from price fluctuation from the most recent 100 terms.

**Determination of Transaction Prices** Transaction prices are determined as the price where stock supply and demand converge \( (\sum_{i=1}^{M} (P_t^i) \omega_t^i) / P_t \). In this case, the total asset \( (P_{t}^i) \) of investor \( i \) is calculated from transaction price \( (P_t) \) for term \( t \), profit \( (y_t) \) and total assets from the term \( t-1 \), stock investment ratio \( (w_{t-1}) \), and risk-free rate \( (r_t) \), as

\[
F_t^i = F_{t-1}^i \cdot (\omega^i_{t-1}) \cdot (P_t + y_t) / P_{t-1} + (1 - \omega^i_{t-1}) \cdot (1 + r_t)
\]

**Rules of Natural Selection in the Market** The rules of natural selection can be identified in this market. The driving force behind these rules is the desire for cumulative excess profit (Goldberg, 1989). The analysis of natural selection consists of the following two stages: (1) the identification of investors who alter their investment strategy, and (2) the actual alteration of investment strategy (Takahashi et al., 2003, 2004). Each investor must decide whether they should change investment strategies based on the most recent performance of each 5-term period (after 25 terms have passed since the beginning of market transactions). The higher the profit rate obtained most recently is, the lesser the possibility of strategy alteration becomes. The lower the profit, the higher the possibility becomes. Specifically, when an investor could not obtain a positive excess profit for the benchmark portfolio profitability, they are likely to alter their investment strategy with the probability below:

\[
p_i = \min(1, \max(-100 \cdot r_{\text{cum},i}, 0))
\]

Here, however, \( r_{\text{cum},i} \) is the cumulative excess profit for the most recent benchmark of investor \( i \). Measurement was conducted for 5 terms, and the cumulative excess profit was calculated as a one-term conversion.

When it comes to deciding on a new investment strategy, an investment strategy that has a high cumulative excess profit for the most recent five
terms (forecasting type) is 'naturally', more likely to be selected. Where the strategy of the investor \( i \) is \( z_i \) and the cumulative excess profit for the most recent five terms is \( r_{\text{cum}}^i \), the probability \( p_i \) that \( z_i \) is selected as a new investment strategy is given as
\[
p_i = \frac{e^{(\alpha r_i^{\text{cum}})}}{\sum_{i=1}^{M} e^{(\alpha r_i^{\text{cum}})}}
\]

Those investors who altered their strategies make investments based on the new strategies after the next step.

**ANALYSIS RESULTS**

Firstly, a situation where passive investors don’t exist is analyzed. Then, a situation where passive investors are introduced is analyzed.

*When There are not Passive Investors.* Fig. 3 and 4 illustrate the case where both fundamentalists and informed traders exist in the financial market. In this case, the number of informed traders is one (fundamentalist: informed trader=999:1). Fig. 3 and 4 show the transition of stock prices and cumulative excess return of each investor. From the result, it is confirmed that informed traders get positive cumulative excess return throughout investment periods. This result indicates that holding future information could contribute to improving investment performance. In this sense, this result suggests the validity of active investment strategies.

Fig.3. Price transitions (fundamentalist: informed trader=999: 1).

Fig.4. Transitions of cumulative excess return (fundamentalist: informed trader=999: 1).

Fig.5 shows the transition of cumulative excess return of each investor where the number of informed traders is ten (fundamentalist: informed trader=990:10). In this case, the cumulative excess return that informed traders obtain become significantly lower, when compared to fig. 4. These results suggest that the effectiveness of active investment strategies is influenced by other investors’ behaviors.
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Fig. 5. Transitions of cumulative excess return (fundamentalist: informed trader=990: 10).

Fig. 6 shows the transition of cumulative excess return of each investor where five types of investors exist in the market. In this case, the number of informed trader is one, and the number of other types of investor is equal (fundamentalist: latest: trend chaser: average investor: informed trader=249: 250: 250: 250: 1). In this case, informed trader is also able to get positive cumulative excess return.

Fig. 6. Transitions of cumulative excess return (fundamentalist: latest: trend chaser: average investor: informed trader=249: 250: 250: 250: 1).

When there are Passive Investors

Fig. 7 shows the transition of cumulative excess return of each investor when there are six types of investors including passive investor. In this case the number of fundamentalist is one, and the number of other types of investor is equal (fundamentalist: latest: trend chaser: average investor: passive investor: informed trader=199: 200: 200: 200: 1). In this case, informed trader is able to get positive excess return. This result indicates the validity of active investment strategy even when passive investors exist in the market from the short-term’s viewpoint.


Fig. 8 and 9 illustrate the case where natural selection rule works in the market. In this case, the number of fundamentalist is one (fundamentalist: latest: trend chaser: average investor: passive investor: informed trader=199: 200: 200: 200: 200: 1). From these results, it is confirmed that the number of passive investor increases as time step goes, and eventually, all investors employ passive investment strategy. Although under this condition, informed trader could get more return in the short-term, the number of passive investor, however, increases as time step goes due to forecast error of informed trader. (For a detailed analysis about forecast accuracy, see Takahashi (2010).) These results indicate the effectiveness of conducting passive investment strategy, which is consistent with traditional asset pricing theories. Market prices, however, do not reflect fundamental values from around the middle of the transaction period. This is due to the absence of fundamentalists in the market (Takahashi et al., 2007b; Grossman and Stiglitz, 1976). (This is one of the drawbacks of a passive investment strategy. See Takahashi (2007) for a detailed analysis about passive investment strategy.) Fig. 10 shows the case where the same number of six types of investors exist in the market (fundamentalist: latest: trend chaser: average investor: passive investor: informed trader=167: 167: 167: 167: 166: 166). The same results are confirmed in this case. Even when informed traders have more predictive power, passive investment strategy is still valid. In this sense, passive investment strategy is considered to be adaptive investment strategy. Detailed analysis is planned for the future.


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SUMMARY
In this paper, we have analyzed the validity of passive investment strategies in financial markets through agent-based modeling. Our financial simulator is enough powerful to analyze such various kind of phenomena emerged in financial market. The experimental results have suggested that (1) active investing could get positive excess return in the short-term periods; (2) passive investing is effective even when the introduction of active investors holding future information. These results contribute to a clarification of how prices fluctuate in financial markets. The results obtained in this analysis are notable from both academic and practical business view points. In this research, we mainly analyzed the market where fundamentalist have significant influence on the market. A more detailed analysis that considers extreme market conditions -such as a ‘bubble’ or ‘crash’ should be included in future research.

REFERENCES
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Appendices

List of parameters
This section lists the major parameters of the financial market designed for this paper. The explanation and value for each parameter is described.

\[
\begin{align*}
M &: \text{Number of investors (1000)} \\
N &: \text{Number of shares (1000)} \\
F_i^t &: \text{Total asset value of investor } i \text{ for term } t (F_0^i = 2000: \text{common}) \\
W_i &: \text{Ratio of stock in benchmark for term } t (W_0 = 0.5) \\
w_i^t &: \text{Stock investment rate of investor } i \text{ for term } t (w_0^i = 0.5: \text{common}) \\
y_i &: \text{Profits generated during term } t (y_0 = 0.5) \\
\sigma_y &: \text{Standard deviation of profit fluctuation (0.2/\sqrt{200})} \\
\delta &: \text{Discount rate for stock (0.1/200)} \\
\lambda &: \text{Degree of investor risk aversion (1.25)} \\
\sigma_n &: \text{Standard deviation of dispersion from short-term expected rate of return on shares (0.05, 0.1)} \\
a &: \text{Degree of selection pressure (10)} \\
c &: \text{Adjustment coefficient (0.01)} \\
\end{align*}
\]

\[
\begin{align*}
\Delta r_{i}^{\text{im}} &: \text{Expected rate of share return as estimated from risk etc.} \\
\sigma_{i}^{(t)} &: \text{Assessed value of standard deviation of share fluctuation (of investor } i \text{) for term } t \\
\sigma_{h} &: \text{Historical volatility of shares} \\
P_i &: \text{Transaction prices for term } t \\
P_{i}^{f(t)} &: \text{Forecast value of transaction prices (of investor } i \text{) for term } t \\
y_{i}^{f(t)} &: \text{Forecast value of profits (of investor } i \text{) for term } t \\
r_{i}^{f(t)} &: \text{Short-term expected rate of return on shares (of investor } i \text{)} \\
a_i &: \text{Price trend on stock until term } t \\
r_{i}^{\text{cum}} &: \text{Cumulative excess return of investor } i \text{ for the most recent five terms} \\
p_i &: \text{Probability that investors’ who alter their strategy will adopt investor } i \text{’s strategy}
\end{align*}
\]