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Abstract

In this paper, an agent-based model of an artificial economic system that includes both commodity and stock markets is developed in order to analyze the influence of producers' financing strategies for investing in production equipment on the basis of the behavior of economic indicators such as GDP, stock prices, and consumer prices. The results indicate that stock market financing leads to higher GDP than bank financing. This is because the decrease in the repayment burden allows producers to increase the investment frequency, thereby resulting in an increase in consumers' disposable income. When corporate financing strategies from both the bank and stock market coexist, the co-movement of average consumer price and GDP is observed, but the average stock price does not move in accordance with the movement of GDP; there is a time lag between them because of the temporary excessive supply of stocks at the time of investment.

Key Words: Agent-Based Modeling, Computational Economics, Commodity Market, Stock Market

1. Introduction

Agent-based modeling (ABM) is widely used in social simulations because it belongs to a class of bottom-up modeling methods in which one expects to explain various social phenomena by modeling an artificial system so that it works with a mechanism similar to that of a real system [1,2]. The application of ABM in macroeconomic systems constitutes an important research field as numerous social phenomena are related to and influenced by the behavior of macroeconomic systems [3].

In the case of ABM for macroeconomic systems, the behavior of the system is influenced by various factors such as the demand and supply in the commodity market [4], public policies [5], behavior of investors in both financial and foreign exchange markets [6-8], etc. Therefore, it is important to reveal the influence of various factors and calculation conditions on the behavior of the artificial economic system in order to develop a useful model that can be utilized for miscellaneous problem-solving, thereby reproducing the fundamental aspects of the behavior of economic system. For example, in an economic system, GDP is influenced by

the flow of funds not only in the commodity goods market but also in the financial market. Such flow of funds between commodity goods market and financial market could be caused by the producer's issuance of new shares and new bonds as the financing for investment as well as the transactions in the stock and bonds markets by the investors. Among these factors, the producer's issuance of new shares is one of the most important factors relating to the interaction between commodity market and financial market.

Although considerable research has been reported on the behavior of the system with a commodity or financial market, not much research in ABM has focused on the interaction between commodity and financial markets caused by the producer's issuance of new shares as the financing for investments.

For instance, a series of study in ABM reported by LeBaron et. al [9,10] deals with the transactions in the financial market, but the producer's issuance of new shares as the financing for investment is not taken into account. Ashraf et. al [11] analyzed the influence of the roll of banks on macroeconomic indicators from the view point of providing funds to the producers who aim to enter or leave the market. Their model includes the interaction between goods and financial markets, taking into account the financial policies by the central bank, but this model also does not take into account the producers issuance of new shares as financing for investment. Some studies in the field of traditional statistical approaches discuss the influence of producer's financing strategies on the firm's market value [12] or analyze the influence of the roll of central bank on GDP [13, 14]. However, there are few studies that analyze the influence of financing strategies of producers on GDP, not only in ABM but also traditional approaches.

In our previous study, the authors constructed a simple artificial economic model comprising consumers, three types of producers, and a bank; it was found that this simple model reproduces fundamental economic behavior such as a loose equilibrium in price, a business cycle caused by capital investment, the influence of money supply on GDP, correlation between the growth rate of GDP and the increasing rate of consumer price, etc. [15, 16].

In the present study, an agent-based model of an artificial economic system that includes both commodity and stock markets is developed on the basis of the authors' previous model and the influence of producers' financing strategies for investing in production equipment on the behavior of economic indicators such as GDP, stock prices, and consumer prices was analyzed. Based on the calculated results, the influence of the interaction between commodity

and stock markets on the behavior of macroeconomic system were discussed.

2. Simulation Model

2.1 Outline of Model

In this study, the agent-based model of an artificial economic system comprises consumers, three types of producers, and a bank as autonomous decision-making agents, as shown in Figure 1. Producers are divided into retailers who produce final products for consumers, wholesalers who produce and supply raw materials for retailers, and an equipment manufacturer who supplies equipment for the production of other types of producers.

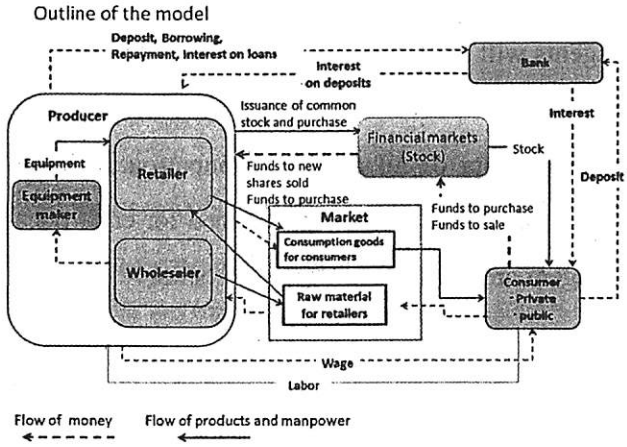

Fig. 1. Outline of the model

Each agent has its own set of attributes and rules of action and interacts with the others during the simulation. A set of attributes includes state variables, such as the amount of deposit, cash, etc. and parameter values, such as the withdrawal ratio of deposits, utilities for each class of products, etc. Owing to the interactions among agents during the simulation, macro-level factors, such as GDP, average market price of commodities, average stock price, Gini coefficient, etc. are obtained from the calculations. The cash $\boldsymbol{M}$ and deposits $\boldsymbol{D}$ of each agent at the beginning of each fiscal period as state variables are given in Equation (1).

$$
\begin{aligned}
M_C^t &= M_C^{t-1} + D_C^{t-1} r_{wd} - E_c^t + b\, I_w^t + a_0 \\
D_C^t &= D_C^{t-1}(1 - r_{wd}) + (1-b) I^t{}_C - a_0 + I_{iC}^t - E_{sC}^t + S_{sC}^t + I_{dC}^t \\
D_P^t &= D_P^{t-1} + S_{pro_P}^t + I_{iP}^t - (E_c^i + \sum_{k\in\{C\}} E_{wk}^t) - E_{rP}^t - I_{dP}^t
\end{aligned}
\tag{1}
$$

where

t : *Fiscal period*, *suffix* : *Agent type*

M : *Cash possessed by agent*

E_c : *Expenditure of consumer to buy consumption product*

r_{wd} : *Ratio of withdrawn to total deposit*

E_s : *Expenditure of consumer to buy stocks*

I_d : *Dividend income*

E_c : *Expenditure of* cost *for materials*

E_r : *Agent's decrease in the balance of loaned money*

a_0 : *Basic consumption of the Keynesian consumption function*

b : *The marginal propensity to consume of the Keynesian consumption function*

D : *Deposit of agent in the bank*

I_w : *Income of consumers.* I_w = *Constwage* + *Bonus*^{t}

I_i : *Balance of interest paid by the bank*

S_s : *Sales of consumer to sales stocks*

S_{pro} : *Sales of producer to sales product*

E_w : *Expenditure of labor* cost

The set of actions of each agent involves period-based units, where one period is assumed to correspond to one month in the real system. During each period, the values of some of the state variables of the agents will change due to interactions among agents. At the end of each fiscal period, each agent settles its accounts through a double-entry bookkeeping method. By summing up the calculated data of all agents, an input-output table with respect to the artificial system is defined and a GDP value is obtained for each fiscal period. The rules of action for each type of agent are assumed as described below.

2.2 Consumer Agent

Consumer agents work with one of the producers where they receive wages, pay tax in line with their income, and buy products and stocks within the limit of cash-in-hand. The details of the rules of actions in the commodity and stock markets are as discussed below.

2.2.1 Action rule in the commodity market

Consumers buy products supplied by retailers according to their utility functions, as defined by Equation (2), within the limit of cash-in-hand, where a weight of utility is randomly assigned to each consumer with a uniform distribution. When there are products of the same class available in the market at different prices, the consumer is assumed to select and purchase the cheapest one among them.

$$utilty = weight \times u(\xi) \quad (2)$$

where,

$u(\xi) = 0, 0.5, 0.2, 0, \cdots$ *if* $\xi = 0,1,2,3,4\cdots$

weight : *weight of utility*

ξ : *Amount of product in which the same product type was purchased in t period*

Budget of consumption B_c is defined as the sum of the Keynesian consumption function and the money withdrawn from the consumer agent's bank accounts, as shown in Equation (3).

$$B_c^t = a_0 + bx^{t-1} + D_C^t r_{wd} \quad (3)$$

2.2.2 Action rule in the stock market

Consumers buy and sell stocks with the aim of making profit in the stock market. It is assumed that they can buy stocks when each of their balance on deposit exceeds 10000 and they can sell stocks of a certain firm when they possess them. The budget for buying stocks B_s is defined as shown in Equation (4), where the ratio for stock investment r_{si} is randomly assigned at the time of investment with a value between 0 and 0.5 with uniform distribution.

$$B_s^t = r_{si} D_C^t (1 - r_{wd}) \quad (4)$$
$$where,\ r_{si} : Ratio\ \ for\ stock\ investment$$

In this study, we examine the following three strategies for buying and selling stocks.

I .Moving-average-oriented strategy

In this strategy, the consumer assesses the future stock price of a firm according to the moving-average of the stock price for the past n periods. The consumer selects and buys stocks so that their expected profit is maximized, as shown in Equation (5), where stands for a random number from a uniform distribution between 0.8 and 1.2, which has a different value for each consumer and is, therefore, specific to each one.

$$\text{maximize}\ \pi_k = \left(\sum_{i=t-n}^{t} p_{k,i} \right) / n \times \delta(0.8,1.2) - sp_{k,t} \quad (5)$$
$$where$$
$$\pi : Expected\ profit$$
$$sp_{k,i} : Stock\ price\ of\ k-th\ firm\ in\ i-th\ period$$
$$\delta(0.8,1.2) : Random\ number\ from\ uniform\ distribution\ between\ 0.8\ and\ 1.2$$

II. Corporation profit-oriented strategy

In this strategy, the consumer buys stocks with a probability that is proportional to the earnings per share averaged for n periods, as given in Equation (6), where n is assumed to be 12.

$$Q_k = A_k / \sum_{i=1}^{m} A_i, \quad (6)$$
$$where,$$
$$Q_k : Probability\ of\ buying\ k-th\ firms\ share$$
$$A_i : Earnings\ per\ share\ averaged\ for\ n\ periods,\ \ i \in \{firms\ \ with\ \ A_k > 0\}$$

III. Random strategy

In this strategy, the consumer randomly buys and sells stocks within the limit of a purchasing budget.

2.3 Producer Agent

Producers hire consumers as employees, pay wages, make production plans, produce products of several types, supply and sell these products in the commodity market, and deposit and withdraw money from the bank in each fiscal period. The wages comprise a fixed salary that is randomly assigned to each employee between a lower and an upper limit and a bonus is given when the profit of the producer is positive. The amount of bonus is defined as the bonus ratio multiplied by the producer's surplus money, and it is uniformly assigned to each of the employees.

2.3.1 Action rule in the commodity market

Retailers and wholesalers decide both the amount and price of each class of product at the production planning stage, where the price is increased or decreased depending on the amount of goods in stock at the end of the previous period. The amount of production is decided such that the probability of the occurrence of being out of stock is less than 5%; this is estimated on the basis of the total sales during the most recent 10 periods. When the estimated price is lower than the running cost per product, the minimum price is set to be the running cost. On the other hand, when the estimated amount of production is less than 80% of the production capacity, the minimum amount of production is set to be that amount. The production capacity Y is defined by a Cobb-Douglas type function, as shown in Equation (7), where K is the number of pieces of equipment for production, L is the number of employees, and α is 0.25. The coefficient A is randomly assigned to each agent between a lower and an upper limit.

$$Y = AK^{\alpha}L^{1-\alpha} \qquad (7)$$

Initially, retailers and wholesalers have one unit of equipment each. They increase that number during the simulation by buying equipment from the equipment manufacturer when the production at maximum capacity continues for longer than a certain critical length of time. According to the financing strategy rule given in the next section, all the necessary money for investment is financed by a bank, the stock market, or by self-financing.

Retailers and wholesalers also have a bankruptcy rule. When a period of no sales with respect to a certain class of products continues for more than a certain critical period, the producer ceases production of that class of product. The producer goes bankrupt when he ceases the production of all classes of products.

Retailers also have a layoff rule. When negative profits continue for more than a certain

critical period, one employee is laid off and assigned to a producer whose amount of accumulated profit is the largest among all producers.

The equipment manufacturer produces equipment in line with the requirements of the retailers and wholesalers, within its production-capacity limit. In the present study, it is assumed that the price of the equipment is constant and the production-capacity limit is four units per period. Further, the production capacity of the equipment manufacturer is assumed to be constant during the simulation.

2.3.2 Financing strategy rule

Retailers and wholesalers finance the amount of money necessary for investing in production equipment from the bank or from the stock market or by self-financing, according to the following five financing strategy rules:

1) Bank financing (strategy A), where all the necessary amount of money is financed by a bank. The borrowed money is constantly repaid in each period for a constant number of consecutive repayment periods, which is assumed to be 120 in the present study. It is assumed that additional investment during repayment periods is forbidden.

2) Stock-market-with-bank financing (strategy B), where producers issue new shares and sell them in the stock market. The money obtained in the stock market is used for buying equipment. If the money raised is less than the amount of money necessary for investment, then any insufficient funds are financed by the bank. After financing from the stock market, the producers pay dividends to the shareholders every fiscal period, where a dividend is defined as the dividend rate multiplied by the face value. In this study, the dividend rate is assumed to be 2%. When the surplus money of a producer is less than the amount of money required for dividends, the producer can set the dividend rate to be 0%. The producer also can buy his own shares in the stock market within the limit of 5% of his deposit, when positive-profit settlement continued for 10 periods.

3) Stock-market-with-internal-funds financing (strategy C), where the producer's money obtained by issuing new shares is less than the amount of money necessary for investment; in such a case any insufficient funds are self-financed from internal funds. The other rule of the producer is the same as that of the stock-market-with-bank-financing strategy.

4) Combination of strategies A and B (strategy D), where the strategy of minimum cost between strategies A and B is selected for financing.

5) Combination of strategy A and C (strategy E), where the strategy of minimum cost

between strategies A and C is selected for financing.

2.4 Bank Agent

The bank keeps the surplus money of other agents in their respective bank accounts and lends money as long-term loans to producers, in line with their demands for investment. The interest rate charged for long-term loans is assumed to depend on the producer's capital ratio; thus, the lending interest rate is increased with decreasing capital ratio, as shown in Table 1. The bank also pays wages to its employees and lends money as short-term loans to producers according to their requirements when they fall short of working capital. It is assumed that the interest rate charged for short-term loans is 1%.

In this study, it is assumed that the initial amount of funds in the bank are very large so that there is no limitation on lending money to meet the demand of producers, except for the rejection of lending during the repayment stage.

Table 1. Lending interest rate for long-term loans

Capital ratio	Lending rate
More than 80%	1.50%
50~80%	2%
30~50%	3%
5~30%	5%
Less than 5%	10%

2.5 Market

In this study, the market comprises a commodity market and a stock market. The market is the place where agents engage in economic activities and interact with each other.

2.5.1 Commodity market

In this study, the commodity market is defined as the place where commodities are transacted, such as products for consumers supplied by retailers, raw materials for retailers supplied by wholesalers, and equipment for production of retailers and wholesalers supplied by an equipment manufacturer. The transactions, such as supplying, buying, and selling, are undertaken by agents in every period. Retailers and wholesalers decide both the amount and price of goods on the basis of the amount of goods in stock at the end of the previous period. The buyers, such as consumers and retailers, purchase goods. When there are goods of the same class available in the market at different prices, buyers purchase the cheapest one among them. Thus, the price of goods purchased is determined in every period as a result of interactions between buyers and sellers. Further, in this study, it is assumed that equipment is produced on order and the price is constant.

2.5.2 Stock market

In this study, the stock market is where stocks are transacted. The stock market is divided into the primary market, which deals with transactions of newly issued shares, and the secondary market, which deals with transactions in existing stocks.

Primary market

Retailers and wholesalers issue new shares to finance the amount of money necessary for investing in production equipment and sell them in the primary market. It is assumed that the face value of a share is constant at 1000. The offer price of a share is determined by a method similar to the book-building method. In other words, the price of own shares outstanding in the secondary market is defined as standard price. A price between 0.9 and 1.1 times the standard price is offered to the consumers. Then, consumers apply to buy the shares at a limit price that is within the range of the offer price. The minimum limit price in financing the necessary amount of money is defined as offer price of newly issued shares.

Secondary market

Consumers buy and sell stocks in the secondary market. The producer also can buy his own shares within the limit of 5% of his deposit when positive-profit settlement has continued for 10 periods. The contract price of stocks is determined so that the bid price is modified until the amount of sell orders coincides with the amount of buy orders.

2.6 Simulation Sequence

A simulation program was constructed using C++, with object-oriented programming. The set of actions for each agent comprise period-based units, where one period is assumed to correspond to one month in the real system. During each period, agents act and interact with each other according to a sequence of seven steps. At the end of the sequence for each period, a GDP value for each period is calculated based on an input-output table obtained by summing each agent's account data. The details of the seven steps describing the sequence of agents' actions are as follows:

1. Agents create a budget plan for consumption, paying wages, or public spending.
2. Wholesalers decide on the amount and price of products to be produced, produce several types of raw materials, and supply these to the material goods market.
3. Retailers decide on the amount and price of products to be produced, purchase raw materials in the material goods market, produce several types of consumption goods, and

supply these products to the consumption goods market.

4. Consumers purchase products in the consumption goods market.

5. Consumers buy and sell stocks. Producers buy his own shares when positive-profit settlement has continued.

6. Each firm pays wages to employees and dividend to the shareholders.

7. Retailers and wholesalers judge the necessity of investment based on total sales in previous periods and, if necessary, invest in equipment. The amount of money necessary for investment is financed from the bank or from the stock market or by firm's self-financing.

8. Each agent settles its accounts using the double-entry bookkeeping method.

2.7 Comparison with real data

The calculated behavior of economic indicators obtained in the present study was compared with the behavior of actual data in the section of discussion. As economic indicators, GDP, consumer price index and stock price were employed. Here, GDP and the consumer price index in the real system were obtained from the data of annual nominal value of "World Economic Outlook Database" presented by the International Monetary Fund World Economic and Financial Surveys [17]. On the other hand, the stock price in the real system were obtained from the data of annual value of "Archives: Historical Data (Nikkei 225)" presented by "Nikkei Indexes" [18]. In addition, all of these data were obtained from the data during the 1990-2010 periods.

3. Simulation Conditions

The parameter values that are constant during the simulation are given in Table 2(a), including the number of agents, which are 300, 60, 9, 1, and 1, for consumers, retailers, wholesalers, an equipment manufacturer, and a bank respectively. The maximum number of fiscal periods for each run of simulation is also constant at 360.

The parameter values given in Table 2(b) include variables that are initially assigned randomly between certain values, but may change during each run of the simulation because of the interactions among agents.

In the present study, we analyzed the influence of financing strategy of producers on the various macroeconomic indicators such as average GDP, consumer's price and the average price of shares in the financial market, where financing strategies are assumed to be 5 strategies as presented A, B, C, D, E strategies in the section 2.3.2. In order to analyze the

influence of each of the strategies, it was assumed that all of the producers have the same strategy in each of the simulation runs. In addition, it was also assumed that the investment strategies of consumers in the financial market consists of 3 strategies such as "Moving-average-oriented strategy", "Corporation profit-oriented strategy", "Random strategy" and the ratio of the number of consumers who invest according to each of 3 strategies is assumed to be the same.

Table 2. Fixed parameters and initial values of variable parameters

(a) Parameter values of the base run

Maximum fiscal periods	360
Number of consumers	300
Number of retailers	60
Number of wholesalers	9
Number of equipment makers	1
Number of banks	1
Fixed salary	7000~7500
Bonus ratio	0.95
Number of product classes	12
Class of product with positive utility	3 of 6
Weight of utility	0.3~1.1
Loan interest	3%
Deposit interest rates	0.50%
Repayment period	120
Investment value	500000
Critical flag number to quit production	20
The lower limit of production	70% of its capacity
Increasing production capacity flag	10
Minimum holding amount required to participate in equity investment	10000
Nominal value	1000
Dividend rate	2%

(b) Initial conditions whose value may change during each run of simulation

Consumer deposit	30000~50000
Capital of R and W	80000~160000
Capital of equipment maker	200000~220000
Capital of bank	96000000 ~104000000
Price of wholesaler products	130~160
Price of retailer products	2850~3150
A in equation (4) for W	300~200
A in equation (4) for R	18~8

Table 3. Condition of analysis of the influence of financing strategy on economic indicators

	Analysis of the influence of financing strategy on economic behaviors				
	Condition of Strategy A	Condition of Strategy B	Condition of Strategy C	Condition of Strategy D	Condition of Strategy E
The funding strategy which all the producers adopt	Loans from banks financing	Loans from banks and equity financing	Internal funds and equity financing	Combination of strategy A and B	Combination of strategy A and C
The ratio of investment strategy which the consumers adopt	Moving-average-oriented strategy : 33.3% Corporation-profit oriented strategy : 33.3% Random strategy : 33.3%				

4. Simulation Results

4.1 Influence of financing strategies on the behavior of GDP

The influence of financing strategies on the chronological change in GDP is shown in Figure 2(a). Chronological change in the total amount of money for investment is depicted in Figure 2(b).

In the cases of bank financing and stock-market-with-bank financing, the GDP shows up-and-down movement in most periods. This is because, as both strategies include bank financing, inflow of funds from the bank into the market and outflow of funds from the market into the bank occur periodically during the simulation. The inflow of funds into the

market occurs due to the investment in production equipment, thereby resulting in an increase in GDP, while outflow of funds from the market occurs due to the repayment of loans, thereby resulting in a decrease in GDP. The basic mechanism of this business cycle is discussed in the authors' previous work [15]. On the other hand, in the case of the stock-market-with-internal-funds financing, periodical movement in GDP disappears, as shown in Figure 2(a). This is because, as this type of strategy does not contain bank financing at all, there is no inflow and outflow of funds in the market.

As compared with bank financing, it is evident from Figure 2(a) that stock-market-with-internal-funds financing yields higher GDP. This is because the decrease in the repayment burden, which is brought about by financing in the stock market, allows producers to increase the investment frequency, as illustrated in Figure 2(b), thereby resulting in an increase in consumers' disposable income.

Further, it is evident from Figures 2 that the stock-market-with-internal-funds financing strategy yields much higher GDP than those of other strategies. This is because, in addition to the effect of decreasing repayment burden, the funds from producers' bank accounts are recirculated in the market due to self-financing with internal funds. In turn, this increases the consumers' disposable income, thereby resulting in an increase in the investment frequency of producers, as shown in Figure 2(a). The decrease in the repayment burden also contributes to an increase in the investment frequency.

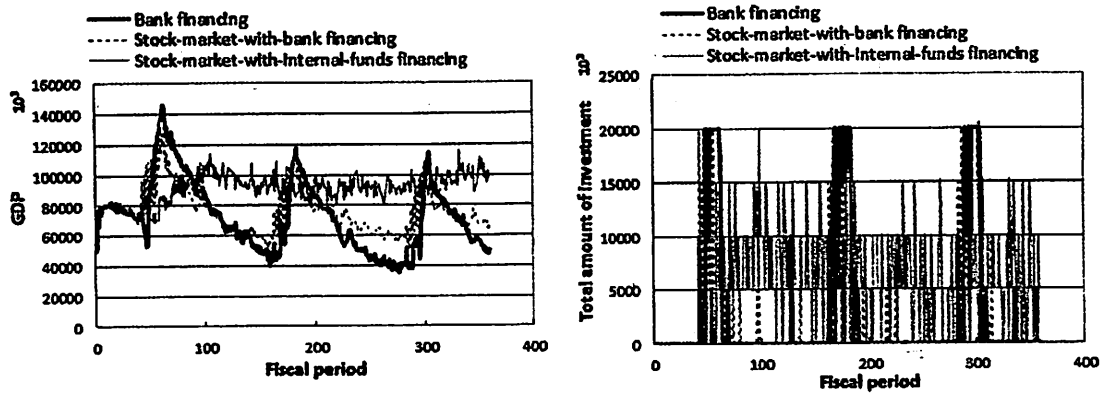

Fig.2. Influence of financing strategies on (a) GDP (left) and (b) the frequency of investment(right)

4.2 Mutual dependence among GDP, consumer prices, and stock prices

The mutual dependence among GDP, average consumer price, and average stock price was analyzed for each financing strategy. In the case of bank financing, co-movement of average product price and GDP is observed, as illustrated in Figure 3. This tendency was also observed in the real system, as pointed out in the authors' previous work [16]. The reason for

this tendency is that there is a clear relationship between total sales of producers and total income of consumers because consumers' income is paid from the producers' total sales.

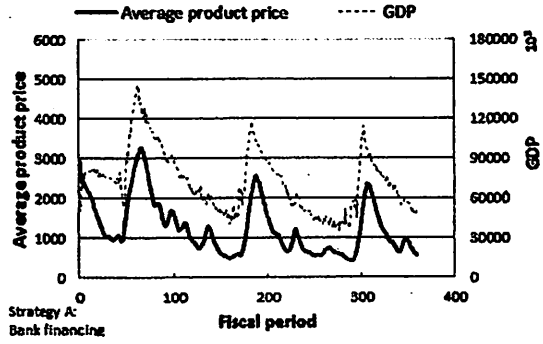

Fig.3. Chronological change in GDP and consumer prices in the case of bank financing strategy.

In the case of the stock-market-with-bank financing strategy, co-movement of average product price and GDP is also observed, but the average stock price does not move in accordance with the movement of GDP and there is a time lag between them. This tendency is caused because, at the beginning of the booming stage, newly issued stocks due to the producers' investment in production equipment result in an excessive supply of stocks in the stock market for certain periods, thereby causing the decrease in average stock price; on the other hand, the investment results in an increase of money supply in the market, thereby causing an increase in consumers' income and demand, which in turn results in an increase in average product price, as shown in Figure 4. Thus, there is a time lag between the average consumer price and average stock price.

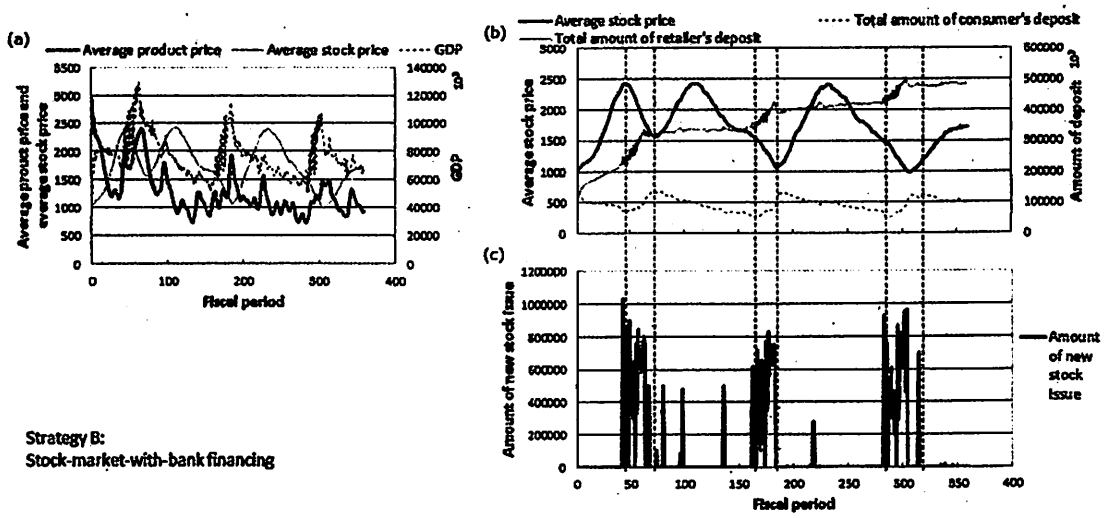

Fig.4. (a) Chronological change in GDP, average product price, and average stock price in the case of stock-market-with-bank financing strategy (upper left). (b) Chronological change in average stock price, consumer's deposit and retailer's deposit (upper right) and (c) newly issued shares (lower right) in the case of stock-market-with-bank financing strategy.

In the case of the stock-market-with-internal-funds financing strategy, co-movement of average product price and GDP is also observed, as depicted in Figure 5. On the other hand, average stock price does not exhibit co-movement with average product price and continues to increase in each period, as shown in Figure 5. This tendency is caused because, in addition to the effect of a decreasing repayment burden, the funds from producers' bank accounts are recirculated in the market through self-financing with internal funds. In turn, this increases the consumers' disposable income, thereby resulting in an increase in the investment frequency of producers. As some part of the consumers' disposable income is used for buying both commodity goods and stocks, it is considered that average prices of products and stocks are determined as result of demand and supply in both markets.

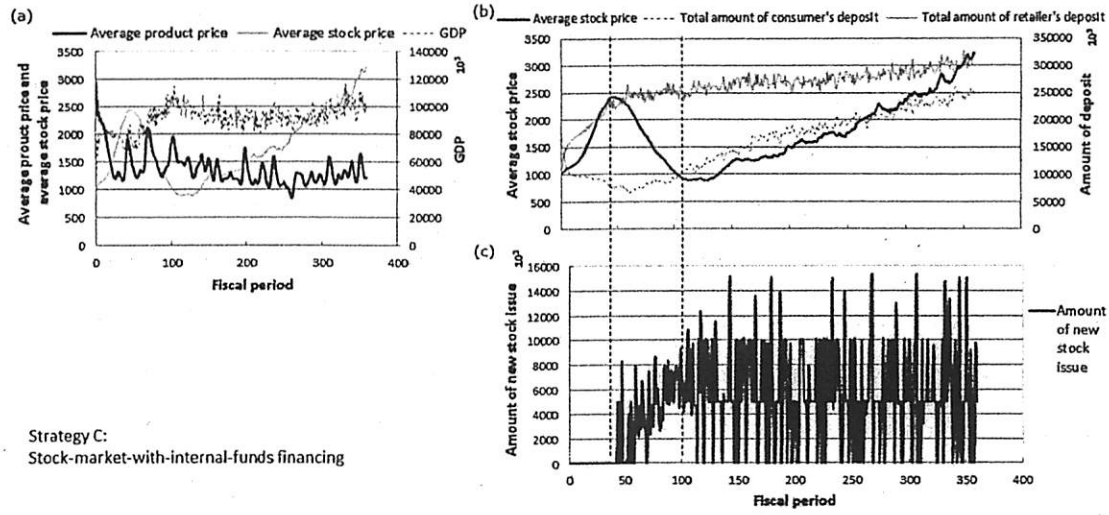

Fig.5. (a) Chronological change in GDP, average product price, and average stock price in the case of the stock-market-with-internal-funds financing strategy (upper left). (b) Chronological change in average stock price, consumers' and retailers' deposits (upper right) and (c) newly issued shares(lower right) in the case of the stock-market-with-internal-funds financing strategy.

4.3 Influence of the mixed financing strategy on the behavior of GDP

Chronological change in GDP is depicted in Figure 6 for bank financing, financing with a combination of strategies A and B (strategy D), and financing with a combination of strategies A and C (strategy E), where strategy A is the bank financing strategy, strategy B is the stock-market-with-bank financing strategy, and strategy C is the stock-market-with-internal-funds financing strategy.

It is evident from Figure 6 that stock-market financing increases GDP and internal-funds financing has the largest effect in increasing GDP. The reason for this tendency is the same as

explained in 4.1 Moreover, it must also be noted that the cyclic movement in GDP becomes vague when the internal-funds-financing strategy is adopted.

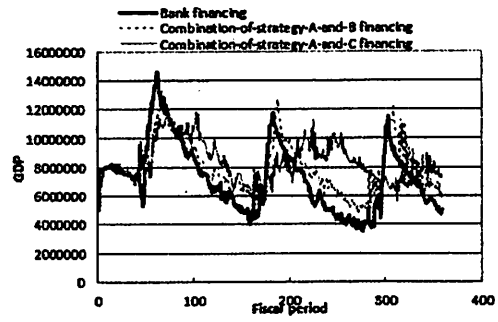

Fig.6. Influence of mixed strategies on GDP

5. Discussion

5.1 Comparison of the behavior of economic indicators between the artificial and real systems.

As a result of the analysis of the influence of financing strategy on the behavior of economic indicators such as GDP, stock prices, and consumer prices, it was found that there is a clear co-movement of GDP with average consumer price as shown in Figures 3 and 4. On the other hand, average stock price does not move in accordance with the movement of GDP and there is a time lag between them as shown in Figure 4. This time lag is caused because of the temporary excessive supply of stocks at the time of investment. In other words, the time lag between average stock price and average consumer price occurs because of the existence of time lag between the increase in consumers' disposable income and the increase in the supply of stocks.

The chronological changes in economic indicators such as GDP, consumer prices, and average stock prices and their mutual dependency have been examined in the real system [17].

As shown in Figure 7, a clear co-movement also exists between GDP and the \consumer price index in the real system, indicating that this tendency is reproduced in the model presented in this paper. This also indicates that positive correlation exists between the GDP growth rates and the rates of consumer price.

Figure 8 shows the relationship between the GDP growth rates and the rates of increase in consumer prices in every fiscal period both in the real system in Japan (Figure 8(a)) and in the artificial system obtained by the simulation (Figure 8(b)).

As shown in Figure 8, positive correlation exists between the GDP growth rates and the

rates of increase in consumer prices both in the real system and artificial system, indicating that this tendency in the real system is also qualitatively reproduced by the model.

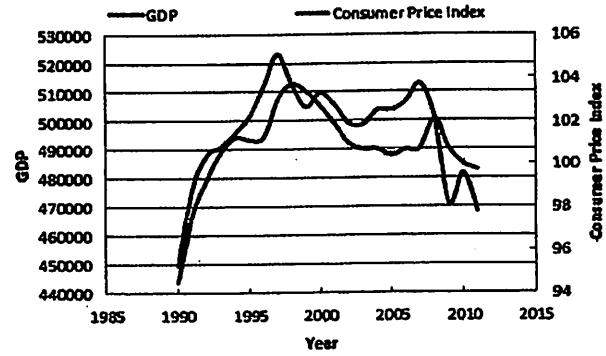

Fig.7. Chronological change in GDP and consumer price index observed in the Japanese economy, showing co-movement between GDP and average consumer price

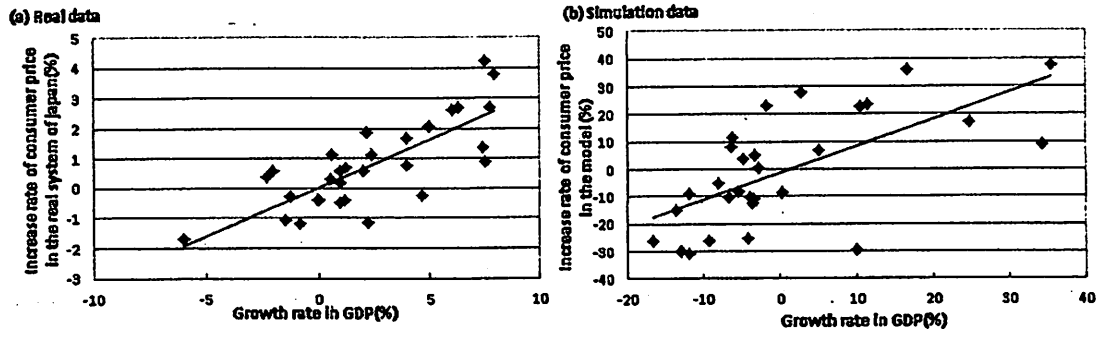

Fig.8. Relationship between increasing of the consumer price and GDP growth rate (a) in the real system and (b) in the modeled system in the case of stock-market-with-bank financing strategy.

On the other hand, the average stock price also does not move in accordance with the movement of GDP or the average consumer price in the real system, as is evident from Figures 9. Figure 9 indicates the chronological movement of stock prices, GDP and average consumer prices in the real system [18].

In addition, Figure 10 shows the relationship between the GDP growth rates and the rates of increase in stock prices in every fiscal period both in the real systems (Figure 10(a)) and in the artificial system obtained by the simulation (Figure 10(b)). As shown in Figure 10, positive correlation does not exist between the GDP growth rates and the rates of increase in stock prices both in the real system and artificial system, indicating that this tendency in the real system is qualitatively reproduced by the model.

As mentioned above, there is a clear co-movement of GDP with average consumer price,

while average stock price does not move in accordance with the movement of GDP both in the real system and artificial system, indicating that the obtained results reproduce the behavior of economic indicators in the real system.

The non-co-movement of stock prices with GDP in the present study is caused by the temporary excessive supply of new stocks due to the producers' financing for investment as a result of interaction between goods market and financial market.

The non-co-movement of stock prices with GDP in the real system is considered to be caused not only by the new issuance of stocks by producers but also other factors such as the transactions by the investment trust companies or by the foreign investors. The influence of these factors on stock prices is not taken into account in the present model and remained to be studied as the future research subject.

In addition, the producers' financing strategy affects not only the macroeconomic indicators, as analyzed in the present study, but also the value of each producer in the market, the influenced of which is also remained to be studied as the future research subject.

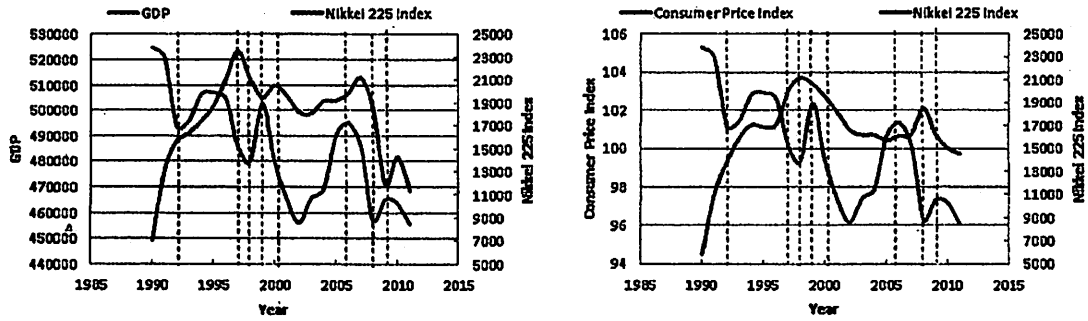

Fig.9. Chronological change in (a) the average stock price and GDP, (b) the average stock price and consumer price index observed in the Japanese economy

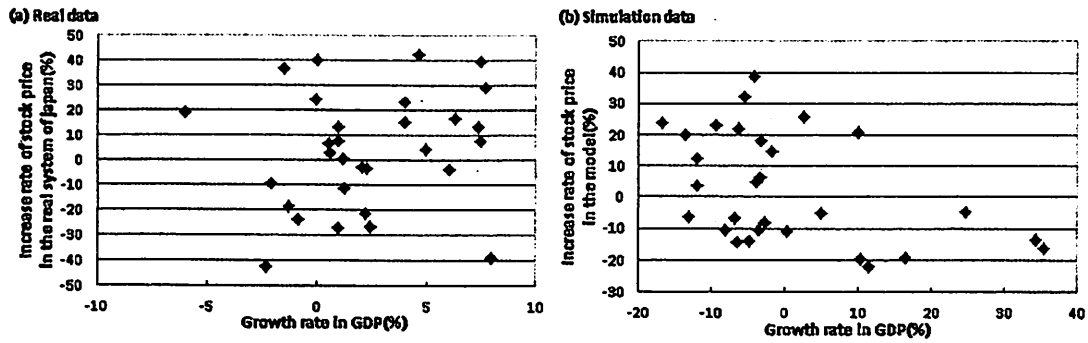

Fig.10. Relationship between increasing the stock price and GDP growth rate in (a) a real system obtained via a macroeconomic model and (b) the simulation model in the case of stock-market-with-bank financing strategy.

5.2 Interaction between commodity and stock markets

As explained in section 4.1, financing from the stock market leads to higher GDP than bank financing. This is because the decrease in the repayment burden allows producers to increase the investment frequency, thereby resulting in an increase in consumers' disposable income. It should be pointed out that this tendency is the result of the interactions between commodity and stock markets because the issuance of new shares by producers and consumer stock purchasing are events in the stock market, while the investment in production equipment and the increase in consumers' disposable income are events in the commodity market. In addition, the increase in consumers' disposable income results in an increase in demand not only in the commodity market but also in the stock market. Thus, the event that occurs in the commodity market influences the event in the stock market and vice versa, and the influence of issuance of new shares on the economic indicators is the result of the interaction between the two markets.

Similarly, the time lag that occurs in the relationship between the average stock price and GDP or the average consumer price is also the result of the interaction between the two markets.

In the real system, many economic indicators are influenced by the interactions among various markets that include not only commodity and stock markets but also others such as the bond market, exchange market, and import and export markets. It requires painstaking work to develop a model that takes into account all of these markets. However, the present study suggests that taking account of interactions among markets is very important and, in some cases, indispensable in reproducing fundamental aspects of economic indicators in agent-based modeling.

6. Conclusion

In this paper, we developed an agent-based model of an artificial economic system that includes both commodity and stock markets, and analyzed the influence of producers' financing strategies for investing in production equipment on the behavior of economic indicators.

1) Financing from the stock market leads to higher GDP than bank financing. This is because the decrease in the repayment burden allows producers to increase the investment frequency, thereby resulting in an increase in consumers' disposable income. In addition, self-financing with internal funds leads to much higher GDP than other strategies. This is

because the funds from producers' bank accounts are recirculated in the market due to self-financing, thereby resulting in an increase in consumers' disposable income and investment frequency of producers.

2) When corporate financing strategies of investment from both the bank and the stock market co-exist, the co-movement of average consumer price and GDP is observed, but the average stock price does not move in accordance with the movement of GDP, and there is a time lag between them because of the temporary excessive supply of stocks at the time of investment. A similar tendency is observed in the real system according to the real data of GDP, the consumer price index, and the Nikkei 225 index pertaining to the Japanese economy. We consider the reason for this tendency to be that there is a time lag between the increase in consumers' disposable income and the increase in the supply of stocks due to the investment of firms.

3) All the findings obtained in the present study are the result of the interactions between commodity and stock markets. This suggests that taking into account interactions between markets is very important in reproducing fundamental aspects of economic indicators in agent-based modeling.

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