Influence of the Corporation Tax Rate on GDP in an Agent-Based Artificial Economic System

Shigeaki Ogibayashi and Kousei Takashima

Abstract An agent-based model of an artificial economic system, including the government, was developed on the basis of the authors' previous model. This model was used to analyze the factors influencing the relationship between GDP and the corporation tax rate and its mechanism. The findings show that executive compensation and the use of producers' own cash for investment are both indispensable factors for reproducing the negative correlation between GDP and the corporation tax rate, because these actions help redistribute the firm's surplus money to the market. Inefficiency in government expenditure is another indispensable condition. The calculated average multipliers for the reduction of both income tax and corporation tax are in good agreement with real data based on the macroeconometric model.

Key words: Agent-based computational economics, Government, Expenditure policy, GDP, Tax rate, Income tax, Corporation tax

1 Introduction

Agent-based modeling (ABM), used to explain or understand social phenomena via a bottom-up approach, is widely used in social simulations [1, 2]. An important feature of ABM is that, once you have designed a computer program that mimics the desired characteristics of the system in question, you can use it to perform controlled experiments, varying one factor at a time while keeping the others constant [3, 4]. Therefore, ABM provides a new way to understand the behavioral mechanisms of complex macroeconomic systems. A potential area for the application of ABM in the real world is government policy formulation in areas such as tax reduction, public spending, and quantitative monetary relaxation [5, 6].

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From a practical application perspective, a model developer should ensure that the model is as simple as possible [1] but that it considers all important factors required to reproduce the desired phenomena. The factors that need to be incorporated into the model differ according to the phenomena to be reproduced in the real system. In other words, macroeconomic mechanisms can be explained and interpreted by a series of computer experiments in which one constituent factor of the model is changed at a time, with other factors being held constant.

A number of ABM-based research studies have focused on various macroeconomic aspects, such as business cycles, innovation, economic growth, the role of banks, monetary policies, industrial dynamics, and wealth inequality [5-10]. Most of these studies reported some new finding, but the way in which they constructed their models was different in each case. This made it difficult to identify the crucial assumptions of the models, and to what extent these assumptions were important in reproducing the concerned phenomena. Many researchers have also developed practical models that aim to simulate multiple-market economic structures as elaborately as possible [11,12]. However, given the nature of these economic phenomena, these studies have often not fully clarified the structural factors of the model that are important for their reproducibility.

Considering this limitation, the authors of this paper constructed a simple, artificial economic model consisting of consumers, three types of producers, and a bank. This simple model was able to reproduce fundamental economic behavior, such as a loose equilibrium in price, a business cycle affected by capital investment, and the influence of money supply on GDP [13]. Furthermore, the authors extended this model to include government policy to analyze the influence of the tax rate on GDP [14]. While the basic model failed to reproduce the positive influence of a corporate tax reduction on GDP, the extended model clearly reproduced the positive influence of an income tax reduction on GDP. The fact that some factors essential to the corporate tax effect on GDP were not considered in the basic model probably accounts for this result. We also conducted a preliminary comparison of our results with the econometric model estimates of the Japanese government. This comparison suggested that the positive tax reduction effect was most likely reproduced because of the following factors: the unemployment rate, executive compensation, use of internal funds for investment, and purchase of both consumption and durable goods by retailers.

In the present study, the revised model is employed to consider the above factors and to examine their influence on the tax rate-GDP relationship. We analyzed each factor individually to identify those most responsible for the reproducibility of the negative tax rate-GDP relationship. According to our results, the redistribution of a firm's surplus money to the market and inefficiency in government expenditure are both indispensable conditions to the reproducibility of actual phenomena under a balanced-budget condition.

2 Simulation Model

2.1 Outline of model

The agent-based model of an artificial economic system in the present study comprises consumers, producers, a bank, and a government as autonomous decision-making agents. It is assumed that consumers are divided into three types of agent: workers, executives and public workers. They work for one of other types of agent, get wages, pay tax and buy consumption goods at the cheapest price available in the market. Moreover, producers are assumed to hire consumers, produce and sell products, pay wages and tax. They are divided into three types of agent: retailers who produce and supply consumption goods for consumers; raw material makers who produce and supply raw materials for retailers; and an equipment maker who supplies equipment for production for other types of producers. The bank keeps the surplus money of other agents in their respective bank accounts and lends money to producers. The government collects tax from other agents, pays wages to public workers and spends the remaining money on public expenditure. They are heterogeneous agents, who interact with others in the economic activities. Heterogeneities of agents are characterized by state variables and other parameters included in their action rules.

2.2 Sequence of actions

The set of actions for each agent comprises 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 seventh step, a GDP value is calculated for each period. This value is based on an input-output table in the artificial system, which is calculated by summing the account data for all agents obtained at the beginning of the seventh step. The sequence of the agents' actions is as follows:

1. Agents pay unpaid tax for the previous period at the beginning of the current period. After paying tax, agents create a budget for consumption, paying wages, or public spending.
2. Raw material makers decide the amount and price of products to be produced, produce several types of raw materials, and supply them to the material goods market.
3. Retailers decide 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 those products to the consumption goods market.
4. Consumers and the government purchase products in the consumption goods market.

5. Retailers and raw material makers decide the necessity of increasing production capacity on the basis of total sales in previous periods and, if necessary, invest in equipment or employ new workers.
6. Each firm pays wages to employees and executive compensation for executives, and the government pays wages to public workers.
7. Each agent settles its accounts using the double-entry bookkeeping method, where the income or profits for the current term are calculated, based on which the amount of tax to be paid is determined as an unpaid tax. In addition, if necessary, each retailer dismisses a worker, or decides to stop production.

The next section describes the rules each agent follows when making a decision.

2.3 Outline of agents' decision-making rules

2.3.1 Rules for consumers

Consumers create a budget for consumption E_b^t. This budget is defined as the sum of part of their income I^t, defined according to the Keynesian consumption function [14] and a withdrawal ratio of r_{wd} times the bank deposit D^t at each fiscal period t. The formula for the budget is shown in Equation (1), where r_{i_tax} is the income tax rate, a is the consumer's basic consumption, and b is the marginal propensity to consume according to the Keynesian consumption function. The withdrawal ratio r_{wd} is set as a random value for each agent.

$$E_b^t = a + bI^t(1 - r_{i-tax}) + r_{wd}^t D^t \ , \tag{1}$$

When purchasing products in the consumption market, consumers select and purchase products within the limit of their consumption budget according to the utility function for each class of products given by Equation (2). In Equation (2), ξ_i is the number of products purchased for product class i, and δ_i is the weight of the utility. The latter weight is randomly assigned for each agent and each product class i. When there are goods of the same class available in the market at different prices, consumers select and purchase the cheapest available. The value of ξ is reset and returns to 0 at the beginning of the next period.

$$\begin{aligned} utility_i &= \delta_i \times u(\xi) \\ u(\xi) &= 1, 0.5, 0.2, 0 \ldots if\ \xi_i = 0, 1, 2, 3, \ldots \end{aligned} \tag{2}$$

2.3.2 Rules for producers

The retailers and raw material makers decide on the amount and price of the products they will produce. The price of a product of product class i for period t, p_i^t, is determined on the basis of the amount of goods in stock at the end of the previous

period, s^{t-1}, as shown in Equation (3). Here, p_{ave} is the average price of the products sold during the previous period, and γ_i and γ_d are the ratios of increasing or decreasing price. When the estimated price is lower than the running cost per product, the minimum price is set to be the running cost.

$$p_i^t = \begin{cases} (1+\gamma_i)p_i^{t-1} & if \quad s_i^{t-1} = 0 \\ p_{avei}^{t-1} & if \quad s_i^{t-1} > 0 \ \ and \ \ p_i^{t-1} > p_{avei}^{t-1} \\ (1-\gamma_d)p_i^{t-1} & if \quad s_i^{t-1} > 0 \ \ and \ \ p_i^{t-1} < p_{avei}^{t-1} \end{cases} \tag{3}$$

The amount of production is decided in such a way that the probability of being out of stock is less than 5%. This is estimated on the basis of the total sales during the most recent ten periods. If the estimated amount of production is less than 70% of the production capacity, this latter value is set as the minimum amount of production. The production capacity Y is defined by a Cobb-Douglas-type production function [14], as shown in Equation (4). Here, K is the number of units of equipment for production, L is the number of employees, and α is assumed to be 0.25. In addition, A is a proportionality constant randomly assigned to each producer between a lower and upper limit. It is assumed that this value is peculiar to each producer, and represents that producer's technical capability.

$$Y_i(K,L) = A_i K^{\alpha} L^{1-\alpha} \tag{4}$$

Retailers and raw material makers initially have one unit of equipment and a specified number of employees. They can decide to invest to increase their production capacity by increasing either the number of units of equipment or the number of employees. First, they check whether full capacity production has continued for more than a critical number of periods. Full capacity production is fulfilled when all products produced at maximum production capacity are sold within a period. Assuming full production capacity has continued beyond the critical number of period, they calculate their expected profit using both equations (5) and (6). When the profit calculated from equation (5) is greater than that of equation (6), they decide to increase the number of units of equipment. If the profit from equation (6) is the greater of the two, they decide to increase the number of employees. In addition, in Equation (5), it is assumed that the depreciation period of the equipment is the same as the repayment period. Here, p is the price of the product, c is the variable cost per product, r_0 is the borrowing interest rate, F is the total amount required to buy one unit of equipment, N is the repayment period, and w is the fixed wage per employee.

$$\Delta\pi_K = \max_i[(p_i^t - c_i^t)\{Y_i(K+1,L) - Y_i(K,L)\} - (r_0 + 1/N)F] \tag{5}$$

$$\Delta\pi_L = \max_i[(p_i^t - c_i^t)\{Y_i(K,L+1) - Y_i(K,L)\} - w] \tag{6}$$

In the case of investing in equipment, half of the necessary funding is financed by the bank and half is financed by the firm's internal funds. The funds borrowed from the bank are repaid as a fixed amount in each period and for a constant number of consecutive repayment periods. During the repayment periods, additional invest-

ment is not allowed when the total number of investments exceeds a certain upper limit. In the case of investment in equipment, a half of necessary fund is financed by the bank and a half is financed by the firm's internal funds. The funds for investment financed by the bank are constantly repaid in each period for a constant number of consecutive repayment periods. During the repayment periods, additional investment is no longer allowed when the total number of investments exceeds a certain upper limit. In the case of hiring additional employees, the producer advertises the vacant position and announces the fixed wage details in the labor market. The unemployed apply for a job with the company that offers the highest fixed wage in the labor market. Then, the producer randomly selects one of the applicants. The equipment maker produces equipment, within its production capacity limit, as required by the retailers and raw material makers. In the present study, the price of equipment is assumed to be constant.

One executive and several workers are assigned to each of the producer agents. The producers pay a wage to workers and executive compensation to the executive in each period. Wages comprise a fixed salary, randomly assigned to each employee between a lower and an upper limit, and a bonus given when the producer's profit is positive. The total expenditure on wages for each producer E_w^t is described by Equation (7), where W_f is the total amount paid as fixed salaries, W_b^t is the total amount paid as bonuses, EC^t is the amount paid as executive compensation, π^t is the profit before tax, and AC^t is accumulated earnings. In addition, W_b^t is defined as $r_b\pi^t$, where r_b is the bonus ratio, and EC^t is defined as $\pi^t(1-r_b)(1-r_{c-tax}r_e)$, where r_{c_tax} is the corporation tax rate and r_e is the executive compensation ratio.

$$E_w^t = \begin{cases} W_f & if \quad \pi^t < 0 \\ W_f + W_b^t & if \quad \pi^t > 0 \ and \ Ac^t < 0 \\ W_f + W_b^t + EC^t & if \quad \pi^t > 0 \ and \ Ac^t > 0 \end{cases} \tag{7}$$

Retailers also have a dismissal rule. If a period of negative profit continues for more than a certain critical time, one of the employees is dismissed and receives unemployment compensation from the government while searching for a new job. The unemployment compensation ceases after the unemployed person becomes an employee of a new company. In addition, there is a bankruptcy rule. When a given class of product remains unsold for longer than a critical period limit, the producer stops its production. The producer goes bankrupt when the production of all classes of its products stops. The employees belonging to a producer who goes bankrupt are dismissed and become unemployed.

2.3.3 Rules for the bank

The bank retains the surplus money of other agents in their respective bank accounts, earns interest on long-term and short-term loans, and pays wages to its employees and taxes to the government in line with its interest income. The bank lends money as a long-term loan to producers in line with their demands for investment, charging

a 3% interest rate. The bank also lends money as a short-term loan to producers when their working capital for paying fixed wages and/or purchasing raw material becomes sufficiently small. In the present study, the initial amount of funds in the bank is set to be very large so that there is no limitation on lending to producers, except in the case when long-term loans are not fulfilled during the repayment periods.

2.3.4 Rule of Government

The government collects corporation tax and income tax from producers and consumers, respectively, pays wages to public employees, pays social security payments to the unemployed, and uses the remaining money in a given fiscal period for public spending, according to its expenditure policy. Corporation tax is only collected when a producer's profit is positive, and the tax rate is assumed to be constant. Income tax is collected according to the consumer's income, and this tax rate is also assumed to be constant. The public employees' wages are determined for each fiscal period and are equal to the average value of a private employee's combined fixed wage and bonus.

With regards to expenditure policies, market purchasing and firm subsidy, and combinations of the two, are tested. Market purchasing is an extreme case of efficient public spending in which the government directly purchases goods in the market at the market price. This policy corresponds to the extreme case of public works expenditure where the government places job orders with firms in a completely competitive situation at the same price level expected in the market. Firm subsidy is an extreme case of inefficient public spending in which the government evenly distributes funds to producers without any limitations on their use. This policy corresponds to the extreme case of inefficient public works expenditure where the government places job orders at a much higher price level than expected in the market, or pays money for jobs that have no economic value.

3 Simulation Conditions

A simulation program was constructed using C++ using the object-oriented methodology. The simulation conditions are given in Table 1. Table 1(a) shows the fixed parameters with values that remain constant during the simulation. Table 1(b) shows the initial conditions. Here, the values are initially given by a uniform random number, but may change during each simulation run. Table 1(c) shows the simulation parameters as experimental levels. These are constant, but change in each simulation run to clarify their influence on macroeconomic behavior in the artificial economic system.

As shown in Table 1(a), each simulation run includes 360 periods, and the producers' repayment period is assumed to be 120 periods. The simulation parameters

as experimental levels are divided into five categories, as shown in Table 1(c): a standard condition, and analyses of the executive compensation, internal funds, upper limit of investment, and the labor market.

The analysis of executive compensation aims to analyze the influence of the executive compensation rule on the relationship between corporation tax rate and GDP. Without the executive compensation rule, the producer's profit all goes to its bank account. The analysis of internal funds aims to analyze the influence of using internal funds for investment. Without the internal funds rule, the producer finances all its investment through the bank. The analysis of the upper limit of investment aims to analyze the influence of the number of investments during the repayment period. The analysis of the labor market analyzes the influence of the labor market rule when consumers are dismissed and apply for new jobs. Without the labor market rule, the dismissed consumer is automatically employed by the producer with the largest accumulated profit. The standard condition is the basic condition in which none of the rules mentioned above are employed.

4 Simulation Results

4.1 Influence of executive compensation rule

The influence of executive compensation on the relationship between the corporation tax rate and GDP is shown in Fig. 1(a) and Fig. 1(b) under the standard condition and under the condition of the internal funds rule and the increased upper limit rule for the number of investments, respectively. In both cases, the labor market is not taken into account.

As shown in Fig. 1(b), a reduction in the corporation tax rate results in an increase in GDP only when the executive compensation rule and the increased upper limit rule are employed. Thus, the executive compensation rule is considered to be one of the factors responsible for the negative correlation between the corporation tax rate and GDP. In addition, the GDP level is larger in the case with executive compensation, as shown in Fig. 1. This is because the total amount of consumers ' income increases when executive compensation is included.

4.2 Influence of internal funds rule

The influence of using internal funds for investment on the relationship between the corporation tax rate and GDP is shown in Fig. 2 under the standard condition (Fig. 2(a)) and the condition with the same two rules applied: the executive compensation rule and increased upper limit rule for the number of investments (Fig. 2(b)). In both cases, the labor market is not taken into account.

Table 1 Simulation conditions.

(a) Parameter values of the base run

Maximum fiscal periods t	360	Number of consumers	150
Number of retailers	30	Number of material makers	4
Number of equipment makers	1	Number of banks	1
Withdrawal ratio r_{wd}	0-0.5	Weight of utility δ	0.3-01.1
Fixed salary	7000-7500	Basic consumption a	3000
Marginal propensity to consume b	0.7	Executive compensation ratio r_e	95%
Bonus ratio r_b	75%	Investment price	500000
Critical flag number to quit production	20	Critical flag number for dismissal	5
Ratio of increasing price γ_i	0.15	Ratio of decreasing price γ_d	0.1
Deposit interest rates r_{int}	0.5%	Loan Interest r_0	3%
Repayment period N	120		

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

Capital of consumer	30-50$\times 10^3$	Capital of retailer & raw material maker	80-160$\times 10^3$
Capital of equipment maker	200-220$\times 10^3$	Capital of bank	96-104$\times 10^6$
Price of material products	130-160	Price of consumption products	2850-3150
A in equation(5) for raw material maker	200-300	A in equation(5) for retailer	8-18

(c) simulation conditions as experimental levels

	Standard condition	Executive compensation	Internal funds	Upper limit of investment	Labor market
Executive compensation rule	Without	With/Without	With	With	With
Internal funds rule	Without	With	With/Without	With	With
Upper limit of the number of investments rule	1	3	3	1/3	1
Labor market	Without	Without	Without	Without	With/Without
Income tax rate r_{i-tax}	10-30%(5% intervals) / 20%				
Corporation tax rate r_{c-tax}	20% / 10-30%(5% intervals)				
Ratio of firm subsidy	40-80%(10% intervals)				
Ratio of market purchasing	60-20%(10% intervals)				

As shown in Fig. 2, a reduction in the corporation tax rate results in an increase in GDP only when the internal funds are used for investment and the increased upper limit rule for investment is employed. In other words, the negative correlation between the corporate tax rate and GDP is not reproduced under the condition without the internal funds rule, even though the other two rules are employed. Thus, the internal funds rule is considered to be one of the factors responsible for the negative correlation between the corporation tax rate and GDP.

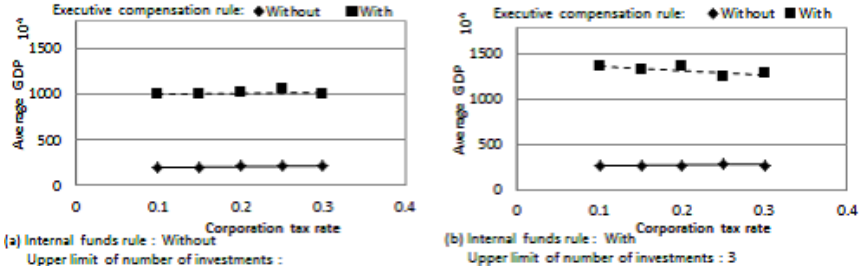

Fig. 1 Influence of executive compensation on the relationship between the corporation tax rate and GDP under (a) the standard condition and (b) with the internal funds rule and increased upper limit rule for the number of investments applied.

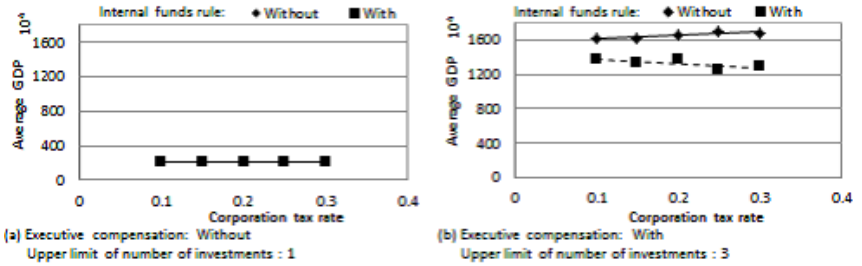

Fig. 2 Influence of the internal funds rule on the relationship between the number of investments and the corporation tax rate under (a) the standard condition and (b) the condition with the executive compensation rule and an upper limit of the number of investments of three.

4.3 Influence of increased upper limit rule for the number of investments

The influence of the increased upper limit rule for the number of investments on the relationship between the corporation tax rate and GDP is shown in Fig. 3 under the standard condition (Fig. 3(a)) and the condition with the executive compensation rule and the internal funds rule applied (Fig. 3(b)). In both cases, the labor market is not taken into account. As shown in Fig. 3, the negative correlation between the corporate tax rate and GDP is clearly obtained when the upper limit of the number of investments is three. However, even in the case where the upper limit of the number of investments is one, the correlation seems to be weakly negative rather than positive. Thus, the factors that are essentially responsible for the negative correlation between the corporate tax rate and GDP are considered to be the executive compensation rule and the internal funds rule. In addition, the upper limit of the number of investments strengthens the tendency of the negative correlation between the corporation tax rate and GDP.

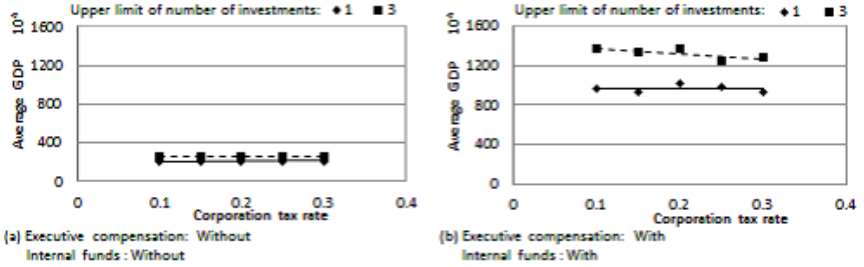

Fig. 3 Influence of the upper limit of number of investments on the relationship between GDP and the corporation tax rate under (a) the standard condition and (b) the condition with the internal funds rule and the executive compensation rule applied.

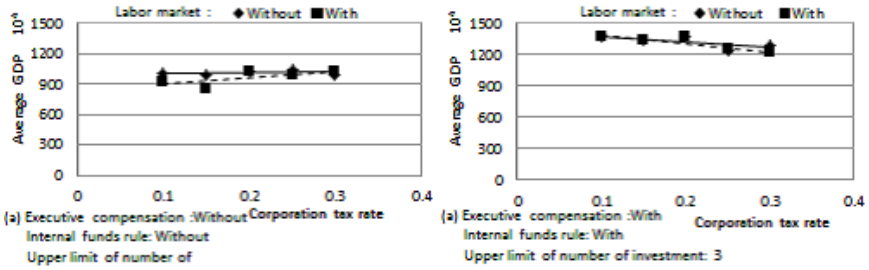

Fig. 4 Influence of labor market rule on the relationship between GDP and corporation tax rate under (a) the standard condition and (b) with the other rules and elements.

4.4 Influence of labor market rule

Under the condition with the executive compensation rule and the internal funds rule, it was found that the negative correlation between the corporate tax rate and GDP is reproduced regardless of whether or not the labor market is taken into account, as shown in Fig. 4. This indicates that the unemployment rate is not an essential factor for the negative relationship between the corporation tax rate and GDP. The reason for this is considered that the contribution by the unemployed to the total demand is not large when compared to that of the other factors.

5 Discussion

5.1 Comparison between the calculated result and the real system

Summarizing the simulation results on the influence of the rules described above, it was concluded that the clear negative correlation of GDP with the corporation tax rate is only reproduced when three of the rules, namely, the executive compensation

Fig. 5 Influence of income tax rate and corporation tax rate on average GDP.

rule, the internal funds rule and the increased upper limit rule, are simultaneously employed. The negative correlation of GDP with the income tax rate is also reproduced under this condition, as shown in Fig.5. It was also found that the labor market is not a responsible factor for the relationship between the corporation tax rate and GDP.

Under the condition where three of the rules are simultaneously employed, the multipliers related to income tax reduction and corporation tax reduction are calculated and compared against the reported data, based on the macroeconometric model presented by the Japanese government [16], under the assumption that this reflects the behavior of the real economic system. The calculated multipliers in the present model, averaged for market purchasing ratios between 40% and 80%, are 0.78 for the income tax reduction and 1.39 for the corporation tax reduction. These values are consistent with the real data in the macroeconometric model, which range between 0.45 and 1.10 for the income tax reduction, and 0.24 and 1.17 for the corporation tax reduction (see Table 2).

5.2 Mechanism of the influence of three rules on the relationship between corporation tax rate and GDP

The chronological changes in the financial assets of consumers and retailers are presented in Fig. 6(a) and Fig. 6(b) for the cases without and with the executive compensation rule, respectively. In both cases, the internal funds rule and the increased upper limit rule for the number of investments are simultaneously applied. As shown in Fig. 6, considering the executive compensation means an increase in financial assets for consumers, but a decrease in financial assets for retailers. The reason for this tendency is that the executive compensation transfers part of the assets of firms to consumers, since executives are a subset of consumers. The executive compensation is thus considered to be one of the factors responsible for the negative correlation between GDP and the corporation tax rate. Here, the reduction in the corporation tax rate increases the net profit of firms, some percentage of which is transferred to the consumer through executive compensation, thus increasing consumers' demand and GDP. In addition, the tendency for the financial assets of consumers to increase

Table 2 Estimated multipliers of GDP and tax revenue when the corporation tax rate is reduced: (a) in the present model and (b) in the real system.

Multiplier due to corporation tax reduction(1% of GDP)					
(a)Simulation results			(b) Data in the real system		
Market purchasing ratio	GDP	Tax revenue	Year	GDP	Tax revenue
40%	-0.25	-2.70	2005	0.45	-5.71
50%	3.00	-4.23	2006	0.97	-4.93
60%	7.69	-2.70	2007	1.10	-4.60
70%	-2.01	-4.01	Average	0.84	-5.08
80%	-1.50	-2.87			
Average	1.39	-3.30			
Multiplier due to income tax reduction(1% of GDP)					
(c)Simulation results			(d) Data in the real system		
Market purchasing ratio	GDP	Tax revenue	Year	GDP	Tax revenue
40%	1.35	-2.38	2005	0.24	-5.71
50%	1.67	-2.39	2006	0.85	-4.28
60%	1.05	-2.49	2007	1.17	-3.80
70%	0.30	-3.05	Average	0.75	-4.60
80%	-0.45	-3.59			
Average	0.78	-2.78			

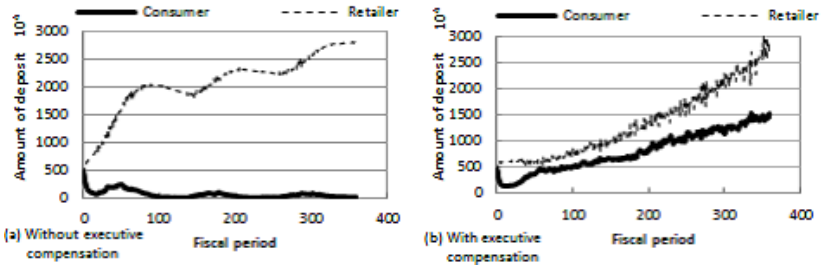

Fig. 6 Influence of the executive compensation rule on the deposit of consumers and retailers under the conditions (a) without compensation and (b) with compensation.

with time is in good agreement with the real data of household deposits presented by the Japanese government [17].

Fig. 7 shows the influence of the internal funds rule and increased upper limit rule on the total number of investments under the condition of the executive compensation rule. As shown in Fig. 7(b), the total number of investments shows a negative correlation with the corporation tax rate only when the internal funds rule and increased upper limit rule are both employed. Hence, the internal funds rule and increased upper limit rule are also factors responsible for the negative correlation of GDP with the corporation tax rate, because both rules cause firms' deposits to circulate in the market and increase consumers' income.

In addition, the inefficiency of government expenditure is also a factor responsible for the negative correlation of GDP with the corporation tax rate. Note that all the

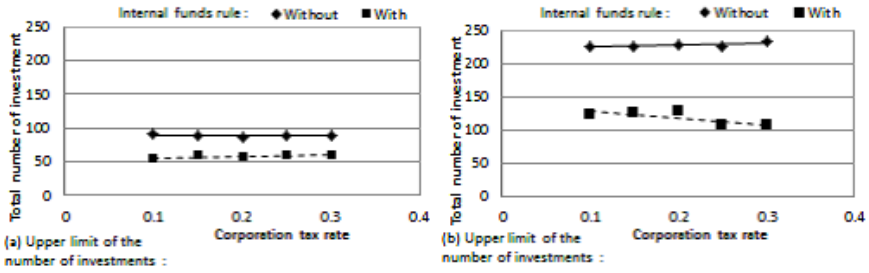

Fig. 7 Influence of the internal funds rule on the relationship between the total number of investments and the corporation tax rate under the condition that the upper limit of number of investments is (a) one and (b) three.

results mentioned above are obtained under the condition that the market purchasing ratio is 0.6, as shown in Table 2(a). If government expenditure is completely efficient, that is, the market purchasing ratio is 100%, no negative correlation between GDP and the corporation tax rate is reproduced in the model. This is because, with 100% market purchasing, increasing the corporation tax rate promotes the transfer of internal funds to the market.

This mechanism is qualitatively understood by the following argument. Consider a company that represents the aggregate of all retailers and raw material makers. Similarly, consider a consumer representing the aggregate of all consumers. For simplicity, we assume there are no public consumers and that tax revenue is used entirely for government expenditure. In addition, we denote the total sales of the company in a certain period as T, the consumption ratio of the consumer as μ, and the efficiency of government expenditure as *eta*. It is also assumed that the fixed wage, bonus, and executive compensation are all included in the ”bonus” category.

With the above assumptions, total sales T becomes the income of the consumer, the tax revenue of the government, and the company’s deposit. Some part of the income and tax revenue will, in turn, be spent on consumption in the market, and so will become the total sales of the company. Once this process is repeated indefinitely, we obtain the total demand for the consumer CC and the total demand of the government CG. In such a case, the consumer demand is given by Equation (8) if government expenditure is neglected, and the government demand is given by Equation (9) if consumer demand is neglected.

$$C_C = \sum_{k=1}^{\infty} T r_b^k \mu^k = T/(1 - r_b \mu) \tag{8}$$

$$C_G = \sum_{k=1}^{\infty} T(1 - r_b)^k r_{c-tax}^k \eta^k = T/\{1 - (1 - r_b) r_{c-tax} \eta\} \tag{9}$$

According to Equation (8), the consumer demand is an implicit function of the corporation tax rate and increases with an increase in the total sales of the company. Therefore, if the company spends the surplus money obtained from the tax reduc-

tion on investments, increasing consumer income, or both, but without increasing deposits in the bank, then the tax reduction increases consumer demand and the total sales of the company, thus increasing GDP.

Further, According to Equation (9), the government demand is an explicit function of corporation tax rate and the efficiency of government expenditure. Hence, if government expenditure is more or less efficient, the total demand and GDP increase with the corporation tax rate. Therefore, if GDP increases with a decrease in corporation tax rate, it is due to an increase in consumer demand. When we consider the consumer demand and the demand caused by government expenditure, and we assume government expenditure to be, to some extent, inefficient, a reduction in the corporation tax rate results in an increase in the total demand and GDP. However, this only occurs if the company spends the surplus money obtained from the tax reduction on investments or on increasing consumer income, or both. In other words, the negative correlation between the corporate tax rate and GDP will result if the company redistributes the surplus money to the market. The three rules, namely executive compensation, the use of internal funds for investment, and increasing the upper limit of the number of investments during the repayment period, promote the redistribution of funds from the company's deposits to the market.

Therefore, we conclude that inefficiency in government expenditure and the redistribution of the company's surplus money to the consumer are indispensable conditions for the model to reproduce a negative correlation between GDP and the corporation tax rate. This suggests that, if companies are not willing to use their internal funds for investment, a reduction in the corporation tax rate could result in a decrease in GDP.

6 Conclusion

An agent-based model of an artificial economic system, including the government, was developed on the basis of the authors' previous model. Using this model, we analyzed the conditions required to reproduce the negative correlation between GDP and the corporation tax rate. The findings were as follows:

1. A clear negative correlation of GDP with the corporation tax rate is reproduced only when executive compensation is paid and producers invest in equipment using internal funds and loans from the bank, and under the condition that the upper limit of the number of investments during the repayment period is greater than one. The unemployment rate was found not to be a factor required to reproduce the negative correlation between GDP and the corporation tax rate.
2. Under this condition, the influence of an income tax and corporation tax reduction on GDP was in agreement with the real data. In addition, the consumers' financial assets increase with time, the qualitative tendency of which also agrees with the real data.
3. This result indicates that the redistribution of the company's surplus money to the consumer and inefficiency in government expenditure are both indispensable

conditions for the model to reproduce the negative correlation between GDP and the corporation tax rate. This suggests that, if companies are not willing to use the surplus money from a tax reduction for investment, a reduction in the corporation tax rate could result in a decrease in GDP.

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