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An Examination on the Zombie Theory: An Agent-Based-Approach

Daiki Asanuma
Asahikawa University, Hokkaido Prefecture, Japan

Abstract: This study examines the Zombie theory which claims the survival of low-productivity firms in Japan has prevented economic recovery since, the bursting of the financial bubble in the late 1980s. The existence of so-called "zombie firms" is one reason for the stagnation of the Japanese economy because they prevent more productive companies from gaining market share and thus, reduce productivity gains for the overall economy. This theory easily results in the neoclassical policy statement that is the government should not intervene the natural process of firms' metabolism. So, "doing nothing" is the best way to improve macroeconomic performance. However if the bankruptcy of one firm affects others in its network, this argument does not hold because networked firms can become embroiled in a bankruptcy chain. This study assesses the validity of Zombie theory using computer simulations within a network economy setting. It finds that governmental policies to save bankruptcy candidates improve macroeconomic performance in a network economy. In other words, governmental intervention can be effective in this kind of economy by preventing the propagation of a bankruptcy chain that may embroil high-performing firms.

Key words: Zombie theory, agent based model, credit network, creative distraction process, bankruptcy chain

INTRODUCTION

Since, the bursting of the economic bubble in 1989, the Japanese economy has faced prolonged recession because of low productivity growth (Hayashi and Prescott, 2002). Recent studies such as Ahearne and Shinada (2005), Hoshi (2006) and Caballero *et al.* (2008) have all insisted that low productivity in Japan is the result of the existence of unprofitable and less productive firms which have been termed "zombie firms" (Caballero *et al*., 2008). This study examines whether such low-productivity firms should be encouraged to leave the market in order to improve overall macroeconomic performance.

One line of reasoning suggests that firms that have high debt and low productivity should leave the market because they distort the normal functioning of market competition. If Japanese banks rationally decided to no longer lend to zombie firms such companies would go bankrupt and as a result, Japanese macroeconomic performance would improve. According to this argument which concurs with neoclassical economic growth theories, the main engine for economic growth is total factor productivity. If a population desires high macroeconomic performance, it is necessary to increase productivity. However, the process of "creative destruction", namely where new high-productivity market entrants actively replace old unproductive firms does not necessarily work because of the existence of zombie firms (the most influential economist on the creative destruction is of course, Schumpeter. He "originally advanced the argument that recessions promote a more efficient allocation of resources by driving out bad investments and freeing up resources for more productive uses (Barlevy, 2002). Zombie firms prevent more productive companies from gaining market share, strangling a potentially important source of productivity gains for the overall economy" (Ahearne and Shinada, 2005). Because by definition, the productivity of zombie firms is low, governments or banks must leave them to die. In other words, "doing nothing" is the best way to improve macroeconomic performance.

This argument is based on the assumption that a firm's operations are independent of those of other firms. However, the standard method used to assess this situation, namely the representative agent model can not accurately model the interaction between heterogeneous agents. In particular, it overlooks the chain effect of bankruptcy (bankruptcy chain hereafter) through which the overall macroeconomic system can be affected. It is clear that agents in a macroeconomic system are connected with each other through various networks. In other words, they are dependent on each other.

Indeed when a firm goes bankrupt in the real world, the effect of this event may be propagated throughout its networks in the form of a bankruptcy chain which is frequently seen during periods of economic depression. Therefore, it is difficult to distinguish the cause of bankruptcy because a firm can be involved in the bankruptcy of other firms in its network. This perspective contrasts with Zombie theory, suggesting that the relationship between firm productivity and macroeconomic performance is complicated and thus that zombie theory does not always hold.

If there does exist such a “dual effect” of bankruptcy, policy implications might also differ. In other words, certain firms should be given a lifeline (e.g., through the injection of external funds) even if they are considered to be zombies because in a network economy firms that have relatively high productivity can nonetheless become embroiled in a bankruptcy chain. In Japan, government expenditure tends to be reduced from the perspective of the unprecedented high amount of government deficit. However, the reasons for this reduction have yet to be examined thoroughly.

The present study bridges this gap in the literature by using a computer simulation to analyze whether zombie theory holds in a network economy setting. We use the Agent-Based Model proposed by Gatti *et al*. (2005) in which there are a large number of heterogeneous interacting agents. The interaction between these heterogeneous agents generates “emergence” which “occurs when wholes (e.g., the economy) produce outcomes that differ categorically from those that the parts (e.g., human agents) can produce individually” (Harper and Lewis, 2012).

Further, we consider a network to consist of financial contracts between each firm and a bank. In this sense, the explicit interconnection between firms cannot be detected because we do not introduce direct connections among them. Each firm, however is connected implicitly through the variation in the conditions of financial contracts (i.e., interest rates charged by the bank). When a firm goes bankrupt, non-performing loans have to be wiped out by the same amount as the bank’s net worth which worsens the financial condition of the bank. Therefore, the bank raises interest rates to incumbent firms which can be a trigger of the bankruptcy chain. In this model, therefore the operations of all firms are dependent on those of others.

MODEL

In this study, we build an Agent-Based Model that models the offering of financial aid to low-productivity firms following (Gatti *et al*., 2005).

Firm sector: In the overall macroeconomic system, there are N firms indexed by i = 1, 2, ..., n. The total number of firms N is assumed to be fixed. Each firm has a simple production function $Y_{it} = \phi_{it}K_{it}$ where Y_{it}, ϕ_{it} and K_{it} represent output, productivity and capital stock at time, respectively. We assume that firm’s productivity is the product of its basic level of productivity denoted by and a stochastic element. That is:

$$\phi_{it} = \bar{\phi}_i(1+\varepsilon_{it}) \tag{1}$$

where, ε_{it} follows a uniform distribution that supports $[\varepsilon_{min}, \varepsilon_{max}]$ and E (ε_{it}) = 0. Therefore, the expectation value E (ϕ_{it}) $\bar{\phi}_i$ = is time-invariant.

On its balance sheet, firm possesses capital stock, liability stock L_{it} and net worth A_{it}. The balance sheet condition requires that the following equation must hold for all t:

$$K_{it} = L_{it}+A_{it} \tag{2}$$

We ignore the demand side of the economy. This means that firm’s sales are $\phi_{it}K_{it}$ and it incurs costs of $r_{it}L_{it} + r_{it}^{A}A_{it}$ where r_{it} and r_{it}^{A} represent the charged interest rate and rate of return, respectively. Assuming that the rate of return on net worth is equal to the charged interest rate and that costs other than interest repayments are proportional to interest repayments, profit π_{it} can be written as:

$$\pi_{it} = \phi_{it}K_{it}-gr_{it}K_{it} \tag{3}$$

where, g>1; the present amount of net worth is composed of previous net worth and present profit. Therefore, net worth varies following the rule:

$$A_{it}=A_{it-1}+\pi_{it} = A_{it-1}+\phi_{it}K_{it}-gr_{it}K_{it} \tag{4}$$

From Eq. 4, the threshold level of productivity shock $\tilde{\varepsilon}_{it}$ at which firm i’s net worth is negative can be derived from:

$$\tilde{\varepsilon}_{it} = gr_{it} - \frac{A_{it-1}}{K_{it}} - \bar{\phi}_i \tag{5}$$

If $\varepsilon_{it} < \tilde{\varepsilon}_{it}$, this firm’s net worth is negative. In the case that there is no financial aid for firms that have negative net worth such firms go bankrupt. The probability of becoming a bankruptcy candidate $\Pr(\varepsilon_{it} < \tilde{\varepsilon}_{it})$ is determined by two financial variables: the interest rate charged to this firm and its own net worth. The higher the interest rate is and the smaller this firm’s net worth is the higher this probability becomes. Further, firms that have a high basic level of productivity have greater tolerance to productivity shocks. In other words, the lower the basic level of productivity is the higher the probability of bankruptcy is.

Following Gatti *et al.* (2005), each firm maximizes its expected profit with the probability of becoming a bankruptcy candidate. Firm i's objective function is thus:

$$\prod_{it} = E(\phi_{it})K_{it} - gr_{it} - cY^2 \Pr(\varepsilon_{it} < \tilde{\varepsilon}_{it}) = (\bar{\phi}_{it} - gr_{it}) K_{it} - \frac{c\bar{\phi}_i^2 K_{it}^2}{2\varepsilon_{max}}\left[gr_{it} - \frac{A_{it-1}}{K_{it}} - \bar{\phi}_i - \varepsilon_{min}\right] \quad (6)$$

By differentiating Eq. 6 with respect to K_{it}, we can derive desired capital stock K_{it}^d that is:

$$K_{it}^d = \frac{\varepsilon_{max}(gr_{it} - \bar{\phi}_i) + \frac{c\bar{\phi}_i^2 A_{it-1}}{2}}{c\bar{\phi}_i^2(\varepsilon_{max} + gr_{it} - \bar{\phi}_i)} \quad (7)$$

Each firm's investment I_{it} is determined by the difference between desired capital stock and previous capital stock, namely $I_{it} = K_{it}^d - K_{it-1}$. This investment is financed by the profit earned in previous periods and bank credit newly borrowed in the present period. Therefore:

$$I_{it} = K_{it}^d - K_{it-1} = \Delta L_{it} + \pi_{it-1} \quad (8)$$

where, $\Delta L_{it} \equiv L_{it}^d - L_{it-1}$ and L_{it}^d denotes the credit demand to finance the necessary investment. Finally, we derive the credit demand function by rearranging Eq. 8 with the balance sheet condition $A_{it-1} = K_{it-1} - L_{it-1}$ and substituting Eq. 7 as follows:

$$L_{it}^d = \frac{\varepsilon_{max}(gr_{it} - \bar{\phi}_i) + \frac{c\bar{\phi}_i^2 A_{it-1}}{2}}{c\bar{\phi}_i^2(\varepsilon_{max} + gr_{it} - \bar{\phi}_i)} - A_{it-1} - \pi_{it-1} \quad (9)$$

Government: We assume that the government plays a role in helping bankruptcy candidates (i.e., zombies). It thus adheres to the following process:

- At the end of each period t, the government gathers information on bankruptcy candidates
- Following particular policies, it chooses the candidates to be helped
- The government then allocates resources to each of them. The amount of resources is set as the same amount as the firm's net worth held just before it became a bankruptcy candidate
- The government raises these resources as a lump sum tax from aggregate production to save bankruptcy candidates

Banking sector: The model of banking behavior also rests on Gatti *et al.* (2005)'s formalization as no original view exists in the banking sector (Asanuma, 2013) which analyzes the relationship between bank lending attitudes and financial fragility provides a model based on the same framework with a view of post-Keynesian banking sector). We assume that the role of banks is only to create explicit and implicit financial connections through which external technological shocks can be propagated. At each time t, the bank's balance sheet thus becomes:

$$L_t^S = D_t + E_t \quad (10)$$

where, L_t^S, D_t and E_t represent the stock of lending supply, deposits and the bank's net worth, respectively. The bank faces a quantity constraint in terms of the total amount of credit supply which is proportional to its net worth at period t with a constant v:

$$L_t^S = \frac{E_t}{v} \quad (11)$$

From the balance sheet constraint (Eq. 10) and credit supply rule (Eq. 11), we determine deposits D_t is simply determined as the difference between credit supply and net worth. The bank thus supplies credit to each operating firm following this simple rule:

$$L_{it}^S = \theta \frac{K_{it-1}}{K_{t-1}} L_t^S + (1-\theta)\frac{A_{it-1}}{A_{t-1}} L_t^S \quad (12)$$

where, $X_j = \Sigma_i X_{ij}$, $0<\theta<1$. Equation 12 states that the bank rations its total amount of credit depending on relative firm's capital size and financial validity which are represented by the ratio of a firm's capital stock to total capital stock and by the ratio of a firm's net worth to total amount of all firms' net worth. From the credit demand function (Eq. 9) and credit supply rule (Eq. 12), the interest rate charged to firm i is determined as follows:

$$r_{it} = \frac{\bar{\phi}_i \varepsilon_{max} - c\bar{\phi}_i^2(\varepsilon_{max} - \bar{\phi}_i)(\pi_{it-1} + A_{it-1} + L_{it}) + \frac{c\bar{\phi}_i^2 A_{it-1}}{2}}{g\left[\varepsilon_{max} + c\bar{\phi}_i^2(\pi_{it-1} + A_{it-1} + L_{it})\right]} \quad (13)$$

The bank's profit is thus:

$$\pi_t^b = \Sigma_i r_{it} L_{it}^S - \bar{r}_{t-1}\left[(1-\omega)D_{t-1} + E_{t-1}\right] \quad (14)$$

where, $\bar{r}_j$ and ω represent the average interest rate in period j and a parameter that indicates the monopolistic power of the bank, respectively. In each period, firms may have negative net worth (i.e., be bankruptcy candidates).

If they are not helped, they go bankrupt. The total amount of negative net worth then becomes the stock of non-performing loans, $B_t = -\Sigma_{i\epsilon Qt} A_{it}$, where θ_t denotes a set of bankrupt firms. The bank wipes out these non-performing loans by subtracting them from its own net worth. As a result, the law of motion of a bank's net worth is:

$$E_t = E_{t-1} + \pi_t^b - B_t \quad (16)$$

SIMULATION

For the computer simulation, the following parameters are used: number of firms N = 10000, simulation span max t = 1500, maximum value of productivity $\phi_{max} = 0.15$, minimum value of productivity $\phi_{min} = 0.05$, bankruptcy cost coefficient c = 2, total cost coefficient g = 2.2, initial capital stock $K_{i0} = 1$, initial net worth $A_{i0} = 0.4$, initial borrowing $L_{i0} = K_{i0}-A_{i0}$, monopolistic power parameter $\omega = 0.002$, quantity constraint on lending capacity v = 0.1, initial lending $L_0 = \Sigma_i L_{i0}$, initial net worth of the bank $E_0 = vL_0$, initial deposits $D_0 = L_0-E_0$ and the stochastic technical shock ε_t which is subtracted from uniform distribution with the support [-0.1, 0.1].

Further, we replicate the process of creative destruction in a straightforward way. The number of firms is fixed over the simulation period which means that the number of exits (i.e., bankrupt firms) is equal to that of new entrants. Moreover, every firm has its own basic level of productivity $\bar{\phi}_i$. Therefore if firm m that has a basic level of productivity $\bar{\phi}_m^b$ goes bankrupt, a new firm enters that has the same number m and basic level of productivity $\bar{\phi}_m^n$. However, these two basic levels of productivity are not the same number. We assume that the basic level of productivity for the new entrant is always 3% higher than that of the bankrupt firm. In other words, we set $\bar{\phi}_m^n = (1+0.03)\bar{\phi}_m^b$ (we totally ignore a job matching process pointed out by Mortensen and Pissarides (1994) and Barlevy (2002). Therefore, the new entrants are always operative).

As mentioned above, firms that have negative net worth are categorized as bankruptcy candidates. The following four policies are implemented to save such firms:

- Policy 1: Bankruptcy candidates that are in the top β% of productivity are saved
- Policy 2: Bankruptcy candidates that are in the bottom β% of productivity are saved
- Policy 3: No. bankruptcy candidates are saved
- Policy 4: All bankruptcy candidates are saved

In this simulation, β is set as a parameter with a value of 30. Figure 1 is the dynamics of productions under each scenario. Figure 1 shows the logarithmic GDP dynamics that result from this simulation and contains four lines: policy 1 corresponds to the blue line, policy 2 to the red line, policy 3 to the green line and policy 4 to the cyan line. The blue line, policy 1, realizes the best performance on the level of production. Policy 4 generates the second-best performance. Contrarily, it is unclear that which performances are better between the production performances under policy 2 and 3. However when we see Fig. 2, it is possible to judge policy 2 improves the production performance more than policy 3. This figure

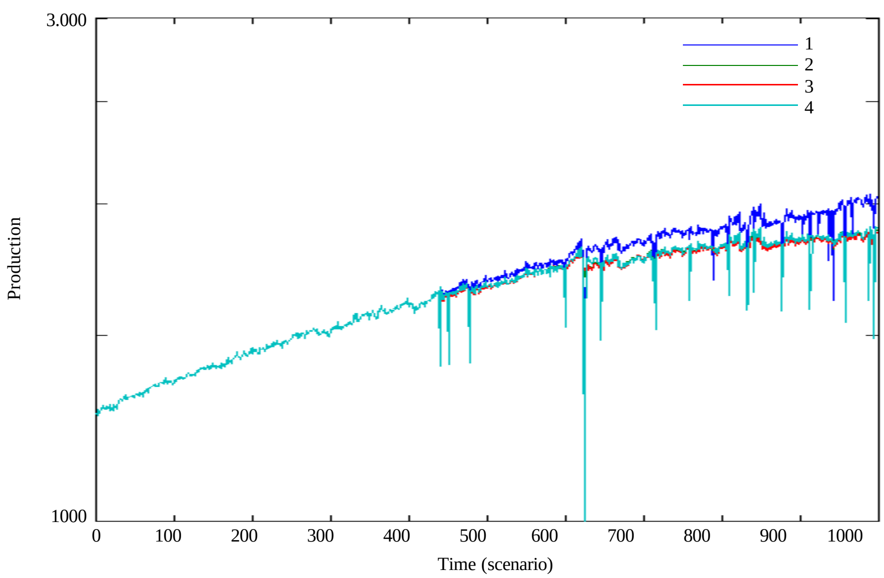

Fig. 1: Production dynamics

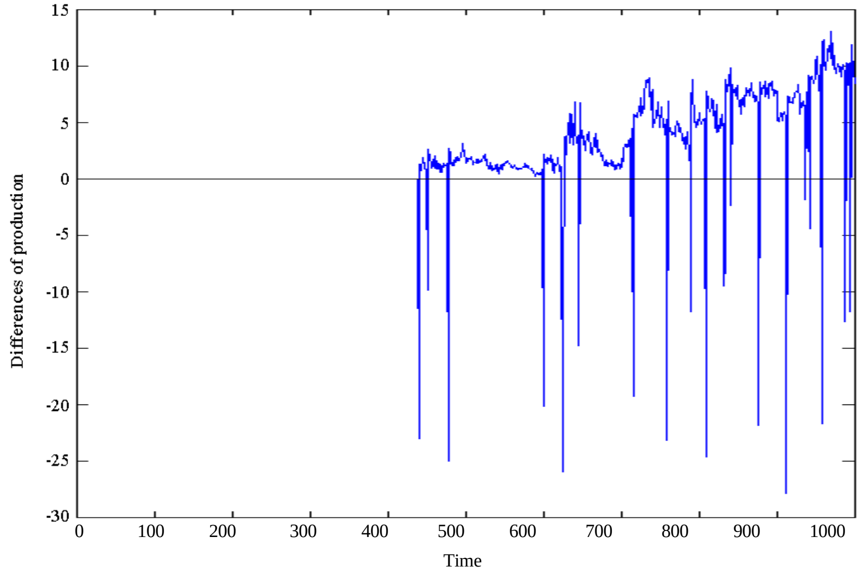

Fig. 2: Differences production between scenario 2 and 3

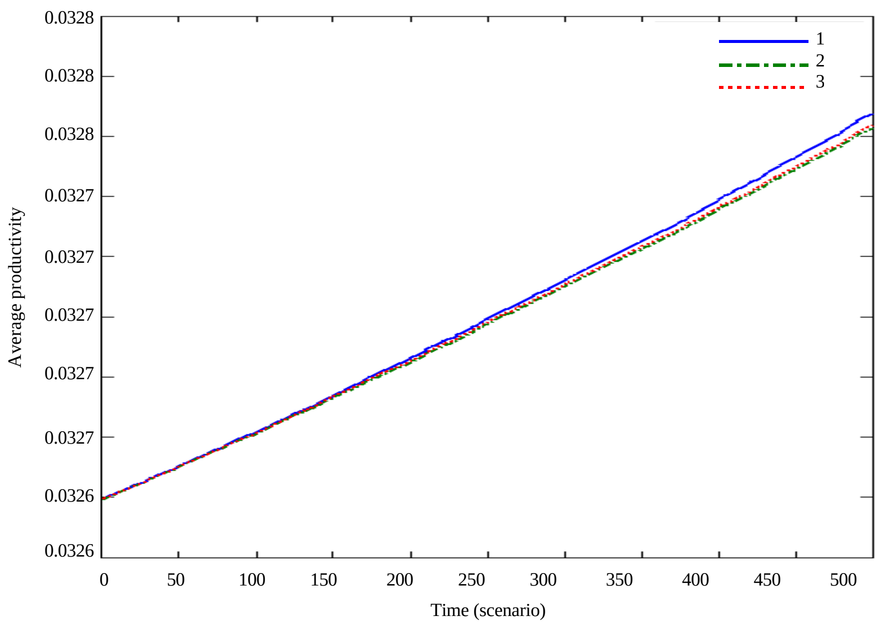

Fig. 3: Dynamics of average productivity

shows the time evolution of the differences of production under policy 2 and policy 3. If this value is positive, GDP under policy 2 to save bankruptcy candidates which have lower 30% productivity, is higher than GDP under policy 3, creative destruction scenario. As we can see from Fig. 3, average productivity tends to be higher on policy 3 than policy 2. However, microeconomic productivity level does not directly connect with aggregate performance.

These results do not support the orthodoxy theory. That is to improve each firm's productivity by the process of creative destruction does not bring the high macroeconimc performance. As we can see from Fig. 3, the average productivity of policy 1 is the highest in the comparison of other policy scenarios (we do not consider policy 4, since creative destruction process does not begin in this scenario). From orthodox economics view point, it is likely that policy 3 realizes the highest average

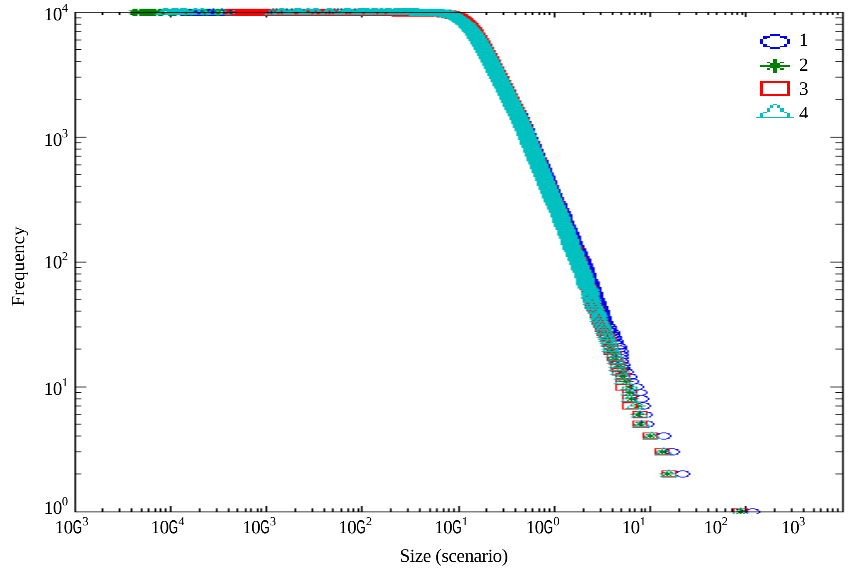

Fig. 4: Firm size distribution (the amount of net-worth at the end period of the simulation)

productivity because the creative destruction process works. We thus confirm that if the government does not intervene in the bankruptcy process, bankruptcy candidates smoothly exit the market and new entrants that have higher productivities continue to operate. As a result, average productivity in the macroeconomy is considered to increase compared with if the government were to intervene to save bankruptcy candidates.

However as shown in that figure, this result does not realize. Over the latter half of the simulation span, average productivity under policy 3 is lower than policy 1. It means that the policy not to intervene the firms' bankruptcy process does not result in the most efficient performance. A "dual effect" of bankruptcy works here. The first effect is the process of creative destruction which is positive. However, because bankruptcy can be a trigger of other bankruptcies, a networked firm may become bankrupt simply because other firms have done so which is negative. In the comparison of policy 1 and 3, the negative effect is stronger. On the contrary, the positive effect is superior in policy 3 to in policy 2.

In summary, the presented results suggest that the relationship between average productivity and aggregate performance is less direct than orthodox economics implies. This novel contribution of the present study thus, points out the factors that orthodox economics ignores. Here, we can find the meaning of fiscal expenditures. From Fig. 1, policy 1 improves performance compared with the other policies even though that policy makes the firm size gap large. And even policy 2 is thought to be better than policy 3. Because low-productivity firms face a high

Table 1: Summary statistics (aggregate variables)

	Policy			
Variables	1	2	3	4
Average bankruptcy	5.7880	5.6685	5.6960	5.7165
Average gerate of growth	1.0e-03×0.4703	0.3978	0.3934	0.403
STD of growth rate	0.0233	0.0055	0.0050	0.0266
Coefficient of variation	0.0202	0.0726	0.0780	0.0151
Policy execution counts	25	22	22	19

bankruptcy probability in our model, the government helps them, thereby allowing the creative destruction process to work and preventing a bankruptcy chain. We thus present a theoretical basis for these kinds of policies in contrast to the often proposed emotional argument.

Next, we see the firm size distribution. Figure 4 gives the firm size (the amount of net-worth firms hold at the end of each simulation period) distribution in log-log plot. The horizontal axis means the amount of net-worth and the vertical axis represents the frequency (in logarithms). Figure 4 shows that the firm sizes are relatively larger on the policy 1, especially around the tail of distribution which means the large size firms survive in this scenario. This is natural because the government saves the bankrupt candidates with high productivities. Actually, Table 1, summary statistics shows the average growth rate of policy 1 is the highest and that of policy 4 is the second. However, the stability of growth passes of these policies is instable because the government must save bankrupt candidates with the large amount of lump sum tax. As a result, the coefficients of variation of these policies are relatively low.

However, when we move our eye on the economic performance per unit capital stock, we can see quite

Table 2: Summary statistics (per unit capital stock)

	Policy			
Variables	1	2	3	4
Average rate of growth	1.0e-0.6×0.4281	0.7717	0.4480	0.2950
STD of growth rate	0.0025	0.0025	0.0025	0.0025
Coefficient of variation	1.03-e03×0.1693	0.3052	0.1772	0.1168

different situation. As is shown in Table 2, the average growth rate is the highest on policy 2. Of course, values are very small and it is difficult to derive the realistic implication from this result. However, this is critically important from the theoretical point of view. Figure 1 and Table 1 represent the aggregate performance. It is inevitable that the aggregate result contains the effect of the total amount of capital stock. However when we want to investigate the relationship between microeconomic productivity and the economic performance per capita, the effect of the total capital stock has to be removed.

The zombie theory asserts that to improve microeconomic productivity means to improve the economic performance per capita with the consideration of representative agent model. Nevertheless, average growth rate might not be improved by the process of creative destruction. It is necessary for the government to intervene to save the 'inefficient' firms with low productivity (Remember that the government saves the firms with productivity from the bottom β%).

CONCLUSION

This study examined the validity of zombie theory. Proponents of this theory insist that the existence of low-productivity firms in the market hinders the creative destruction process that allows the normal entry and exit mechanism to make the overall economy productive. The solution to improving such an economy is simple: encourage all zombies to leave the market. However, this argument implicitly assumes that all bankruptcies occur independently and do not affect other firms' operations. When all firms are connected by an economic network, however, this argument does not hold. Using a computer simulation, this study confirmed that governmental policies to save bankruptcy candidates improve macroeconomic performance in a network economy. In other words, governmental intervention can be effective in this kind of economy by preventing the propagation of a bankruptcy chain that may embroil high-performing firms.

LIMITATIONS

In this study, we refer to the limitations of this analysis. First, the most point is to provide the empirical supports on parameters. As simulating the above model, we set some parameter values following Gatti *et al.* (2005) and set the others discretionally. We expect that this task would be hard. However, it is necessary to improve the robustness of this study. One justification on this study is the net worth distribution among firms. Figure 3 shows the net worth distribution under each policy. It replicates the power low distribution on the log-log plot which is reported frequently on the empirical research of the firm size distribution.

Furthermore, we ignore some important economic structures for example, the interbank market, other types of financial contracts, direct relationship among firms and so on. These things reinforce the network structure in the macroeconomy. Therefore, the scope of our future research is to expand the presented model to include some factors, we ignored here and try the empirical support.

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