The Reform of Higher Education in Japan: A Game-Theoretic Analysis of Intensified Competition

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Keywords: *higher education, competition, cost, university assessment, Nash-game, simulation*

EXTENDED ABSTRACT

There are two types of game-theoretic approach. The first of them attempts to *explain* the social phenomena: *e.g.* why the US and the (former) Soviet Union selected military confrontation, rather than peace. The second is to examine if the social improvement is achieved by *letting members of a group to play games*. As an example of the latter policy-oriented approach, we can refer to the introduction of rewards for the informers in bid rigging, thus *producing* "prisoners' dilemma" for the bidders. This paper follows the second approach. The Japanese government attempted to improve the Japanese academic performance, by changing the funding formula for the Japanese universities. This paper examines if this policy of letting members of a group playing a severer game works.

In 2004, all the national universities in Japan were restructured as the "university corporations", rather similar to the "agencies" of British type. One of the main purposes of the restructuring is to introduce more competition into the higher education in Japan. The higher education is the foundation of the advanced technologies, and it was argued that the US supremacy of technology, which invents new products, stems from the superior higher education in the US. For the promotion of advanced technologies, the reform of higher education was initiated in 2004.

It is well known that the higher education in Japan is not efficient compared with other advanced countries, due to the lack of competition. While the former national Japanese universities are no more national in the sense that teachers are no more public servants, the government basically provides operational funds in research and education. The reform consists in providing funds competitively, in the sense that the more excellent the universities become, the more funds they obtain. In order to examine the government policy, the contribution by Bowen [1980] is utilized.

Bowen [1980] constructed a simple one-university behavior model, which maximizes prestige, not profit, under budget constraint. "Prestige" is objectively evaluated academic performance, and in this paper, it is regarded as the academic performance or academic level. In his model, prestige, or academic level, P, is a function of the quantity and quality of the teaching, T, and research, R, activities undertaken by the university, and it is assumed that $P=TR$. The unit cost of teaching is denoted by c_t, while that of research is denoted by c_r. According to Bowen [1980], this university maximizes academic level under budget constraint, $c_tT+ c_rR=B$, where B is assumed to be a function of P; $B=B(P)=P^\alpha$; B is an increasing function of P. In this paper, the model is extended to two-university model, where $B_1=B_1(P_1,P_2)$, and $B_2=B_2(P_1,P_2)$. Here, B_i is the budget for the ith university provided by the government with $B_1+ B_2=\underline{B}$: constant, and B_i is greater as $P_i/(P_1+P_2)$ becomes greater. In this paper, assuming that the ith university maximizes $P_i=T_iR_i$ subject to $c_{ti}T_i+c_{ri}R_i=B_i(P_1,P_2)$ (i=1,2), we construct a Nash non-cooperative game, and examine if the severer assessment results in higher academic levels. Utilizing simulation approach with the specification, $B_i(P_1,P_2)= \underline{B}\, P_i^\alpha/(P_1^\alpha+P_2^\alpha)$, first, it is shown that the government's policy does not work, so long as $c_{t1}=c_{t2}$ and $c_{r1}=c_{r2}$. Thus, when the cost structure between the two universities is identical, the solution in this Nash non-cooperative game is independent of the government policy parameter α. If the cost structure between the two universities is not identical, it is shown that the government can enhance the academic levels by the introduction of more competition. It is shown that the sum of the two academic levels increases as α increases. It must be noted, however, that when α is large, the solution of this Nash non-cooperative game is unstable, so that further increase of α results in the disappearance of one of the universities. Thus, simple introduction of severer competition cannot enhance the Japanese academic levels.

1. INTRODUCTION

While the game theory has been known even to general public, it is sometimes unnoticed that sufficient care is required to apply it to practical matters. As an example, let us take "prisoner's dilemma". The game theory asserts that prisoners tend to make easy confession, constructing simple pay-off tables for players (prisoners), with the unique game solution: {confess, confess}. It is seldom noticed, however, that if the prisoners are acquitted when they keep silent, the game solution is not unique: {confess, confess} *and* {keep silent, keep silent} are solutions. That is why More [1516] proposed paying rewards for the confessors, and in 2004 by the revision of Japanese monopoly law, the authority is allowed to give rewards for the informers in order to break the bid rigging by letting members of bid rigging play "prisoner's dilemma" game with unique solution.

In Japan, since government provide operational fund for national universities, they are forced to play a game for the fund. When the funding formula is altered toward severer one in this game, the players *attempt* to occupy larger share of the fund, by achieving higher academic levels. Does this policy always *result in* the higher national academic level? This is the motivation of this paper.

In Japan, the reform of higher education initiated by the Japanese government has been under way. The purpose of this reform is to introduce more competition into the Japanese higher education, and to promote technological innovations, and finally construct the US-type vigorous economy.

According to Thurow [1992] the Japanese technologies were characterized as "process technologies", which reduces costs, as represented by Toyota System. The US technologies were characterized as "product technologies", which invent new products, such as semiconductors and mobile phones. It may be argued that Japanese economy manufactured cheap goods using "process technologies", by paying royalties to the US with "product technologies". Indeed, this assertion may be justified, by investigating Japanese trade balance on royalties. In Figure 1, the solid line exhibits the debits (payments) of royalties, while the dashed line exhibits the credits (receipts). In 2003, for the first time in her history, Japanese receipts of royalties exceeded payments (JAPAN STATISTICAL YEARBOOK).

In the 1990s, the contrast between the deflation in Japan and the prosperous "new economy" of the US prompted the argument for the restructuring of Japan. It ranges from the one of financial system including Japanese postal saving to educational system. As for the educational system, it was argued that the US supremacy of technology, which invents new products, stems from her superior higher education.

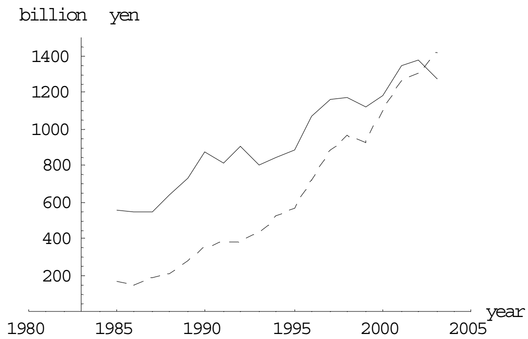

Figure 1: The Japanese Trade Balance on Royalties [1985-2003]

It is known that the expenditure of Japanese government to the higher education has been the lowest among the advanced countries. It is 0.9% of her Japanese National Income, while the corresponding figures of other advanced countries are as follows: the US, 1.4%, Britain, 1.8%, France, 1.2%, and Germany, 2.0% ([The Ministry of Education and Science Report 2002]).

While the Japanese government intends to expand the expenditure, it is also known that the Japanese universities are not efficient, in the sense that there are far less competition than in other countries. There is an agreement of opinions that reforms are required in the Japanese higher education.

In this reform, all the national universities were restructured in 2004 as "university corporations", similar to the "agencies" of British type. One of the methods of achieving the above goal in the new "agency" system is to rigorously assess the academic activity of each university, as well as expanding the financial funds to universities on a competitive basis. As for the rigorous assessment, under the new system, the universities must submit the mid-term (time span of 6 years) plan. In the final year, the academic performance is rigorously assessed, and the expenditure afterwards is adjusted according to the assessment. Regarding the expansion of funds on a competitive basis, in 2002, the Japanese government introduced the 21st Century COE (Center of Excellence) program, which selects excellent research projects proposed by universities and provides huge amount of money on the selected excellent research institutions. In 2003, she extended her program to include the excellent educational methods.

The aim of this paper is to analyze this government policy in economic framework, extending the contribution by Bowen [1980]. Bowen [1980] constructed a simple one-university behavior model, which maximizes prestige, or academic level, under budget constraint. In this paper, his model is extended to two-university model, and Nash-type non-cooperative game is constructed in terms of *Mathematica* simulation, for the purpose of examining if the intensified competition through modified funding method can enhance the academic level of the Japanese universities.

2. Bowen Model and Its Extension: Two-Identical-University Case

Bowen [1980] constructed a simple one-university behavior model, which maximizes prestige, not profit, under budget constraint. In his model, prestige, or academic level, P, is a function of the quantity and quality of the teaching, T, and research, R, activities, undertaken by the university, and it is assumed that $P=TR$. The unit cost of teaching is denoted by c_t, while that of research is denoted by c_r. According to Bowen [1980], this university maximizes prestige under budget constraint, $c_tT+c_rR=B$. An interesting feature in Bowen model is that the budget B is assumed to be a function of P; $B=B(P)$, and B is an increasing function of P. $B(P)$ is called the donating function. He stipulates the university behavior as

$$\max P=TR \quad \text{s.t. } c_tT+c_rR=B(P)=P^{\alpha}. \quad (1)$$

In one-university model, $0<\alpha<1/2$ is assumed. (1) implies that although the university acts as prestige maximizer, it can raise the budget expenses if the prestige increases, since government, firms, and students provide it with more funds. Thus, the university acts as a prestige maximizer, taking account of this factor. It is easy to solve this maximization problem, and the optimum solution is given by $R^*=[(c_r / c_t)^{\alpha}/2\, c_r\,]^{1/(1-2\alpha)}]$ and $T^*= c_r R^*/ c_t$. If $(c_r / c_t)^{\alpha}/2\, c_r >1$, as α approaches 1/2, R^* and T^* becomes infinite.

In this paper, Bowen model is extended to two-university behavior model. Suppose that there are two universities, University 1 and University 2. Each university maximizes academic level, under budget constraint. In this model, it is assumed that the total fund for the universities is fixed at $\underline{B}$. The government allocates the fund for each university according to the share of assessment constructed from donating function. Specifically, University 1 has academic level P_1, which is a function of the quantity and quality of the teaching, T_1, and research, R_1, activities, undertaken by the University 1, and it is assumed that $P_1=T_1R_1$. Donating function is the same as before. University 1 maximizes academic level subject to budget constraint: *i.e.*

$$\max P_1=T_1R_1 \quad \text{s.t. } c_{t1}T_1+c_{r1}R_1=B_1=\underline{B}\, B(P_1)/(B(P_1)+B(P_2)), \quad (2)$$

where P_2 is the academic level of University 2, $\underline{B}$ is the fixed amount of fund given by the government, and $B(P)$ is the same function as in the original Bowen model. It is assumed in this paper that B_1 is provided by the government according to the assessment specified by (2). In other words, α is a policy parameter for the government.

In the same way, University 2 maximizes academic level subject to budget constraint:

$$\max P_2=T_2R_2 \quad \text{s.t. } c_{t2}T_2+c_{r2}R_2=B_2=\underline{B}\, B(P_2)/(B(P_1)+B(P_2)). \quad (3)$$

As in the case for B_1, it is assumed that the government provides B_2 according to the assessment specified by (3), where $\underline{B}$ is the fixed amount of fund given by the government

In this paper c_{ti} and c_{ri} may be different between the two universities. In this section, however, they are the same for the two universities.

$$c_{t1}=c_{t2}, \text{ and } c_{r1}=c_{r2} \quad (4)$$

Thus, two-identical-university behavior model is analyzed in the game theoretic framework. This approach follows that of Fukiharu [2005], which examined the optimal defense game between the two developing countries.

In (2) University 1 maximizes her academic level, given P_2. The optimal academic level is a function of P_2:

$$P_1=\varphi_1(P_2), \quad (5)$$

which is the reaction function of University 1. In (3) University 2 maximizes her academic level given P_1. The optimal academic level is a function of P_1:

$$P_2=\varphi_2(P_1), \quad (6)$$

which is the reaction function of University 2. Equilibrium in two-identical-university behavior model is a Nash non-cooperative solution: *i.e.*

$\{P_1^*, P_2^*\}$ which satisfies $P_1^*=\varphi_1(P_2^*)$, and $P_2^*=\varphi_2(P_1^*)$. (7)

In (7) P_1^* and P_2^* depend on a set of parameters, such as c_{t1}, c_{t2}, c_{r1}, c_{r2}, and α. In this paper, α is a policy parameter for the government, and the increase of α implies "intensified competition", since if $P_1 > P_2$ holds, University 1 receives more fund out of $\underline{B}$ than before and University 2 receives less fund out of $\underline{B}$ than before. The main purpose in this paper is to examine the following question:

Can the government enhance $P_1^*+P_2^*$ by raising α: *i.e.* by introducing more competition into the higher education? (8)

Unfortunately, however, it is not easy to analytically compute the reaction functions, (5) and (6). Thus, in this paper, a simulation approach in terms of *Mathematica* is adopted, where parameters are numerically specified. Suppose that

$c_{t1}=c_{t2}=c_{r1}=c_{r2}=1$, $\underline{B}=100$ and $\alpha=1/10$. (9)

The reaction function of University 1, $P_1=\varphi_1(P_2)$ in (5), is depicted as the solid curve in Figure 2, while the reaction function of University 2, $P_2=\varphi_2(P_1)$ in (6), is depicted as the dashed curve in Figure 2. (As for the construction of this figure in terms of *Mathematica*, see Fukiharu [2003].)

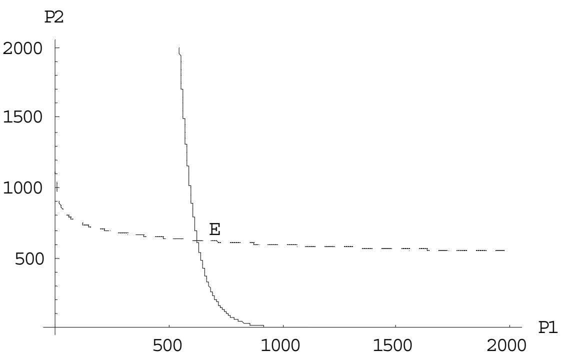

Figure 2: The Reaction Functions when α=1/10 (Stable Solution)

It is easy to check that the Nash non-cooperative solution, $E=\{P_1^*, P_2^*\}$ defined in (7), the intersection of the two reaction functions is stable. It is computed that

$E=\{625,625\}$ (10)

In this situation, suppose that the government intends to enhance the academic levels of the universities by introducing more competition into the higher education. This policy change is represented by the increase of α. Suppose that

$c_{t1}=c_{t2}=c_{r1}=c_{r2}=1$, $\underline{B}=100$ and $\alpha=4/10$. (11)

The reaction function of University 1, $P_1=\varphi_1(P_2)$ in (5), is depicted as the *thick* solid curve in Figure 3, while the reaction function of University 2, $P_2=\varphi_2(P_1)$ in (6), is depicted as the *thick* dashed curve in Figure 3. (As for the construction of this figure in terms of *Mathematica*, see Fukiharu [2003].)

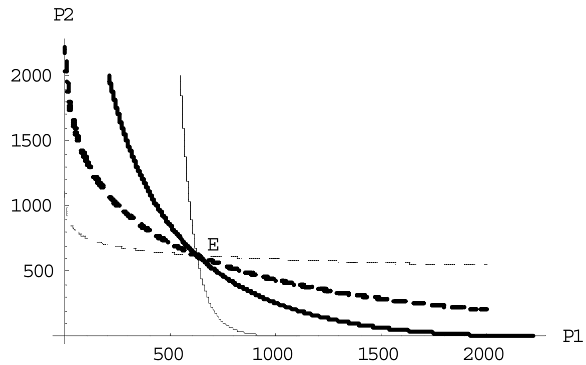

Figure 3: The Reaction Functions when α=1/10 and α=4/10 (Stable Solutions)

In this modified reaction functions case, it is easy to check that the Nash non-cooperative solution, the intersection of the two reaction functions, is given by (10), and it is stable. In other words, the government cannot enhance the Japanese academic level by introducing more competition into her higher education when the cost structure of education is identical.

When α becomes much higher, what would happen? Some may well predict unstable Nash non-cooperative solutions. This prediction is false. In fact, non-existence of Nash non-cooperative solutions emerges, as shown in Figure 4.

When α=1, the reaction functions for University 1 and 2 are depicted as the solid curve and the dashed curve, respectively, while α=2 the reaction functions for University 1 and 2 are depicted as the *thick* solid curve and the *thick* dashed curve, respectively, in Figure 4. In both cases, no solutions of Nash non-cooperative games exist. Presumably, given $P_1(0)$ and $P_2(0)$ arbitrarily, $P_1(\tau)+P_2(\tau)$ would oscillate whereτis time.

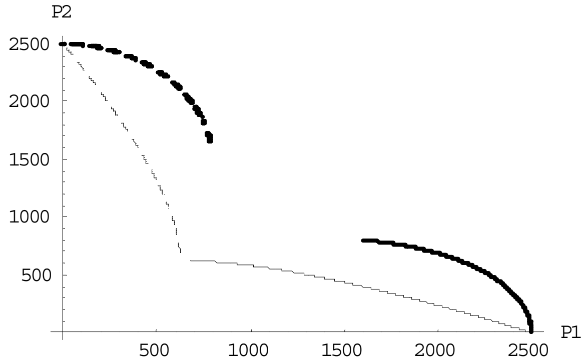

Figure 4: The Reaction Functions when α=1, and α=2 (Non-Existence of Solutions)

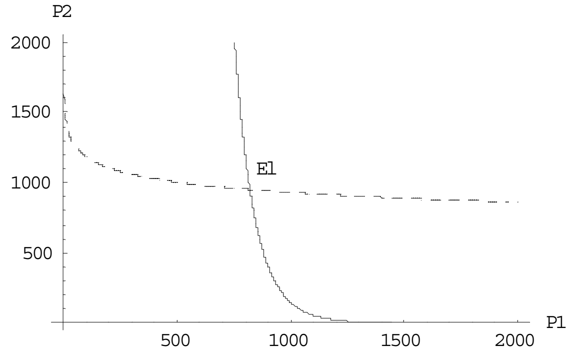

Figure 5: The Reaction Functions when α=1/10: Differentiated Advantage I (El: Stable Solution)

3. Two-Differentiated-University Case

In this section, we assume that two universities are differentiated in the cost structure. Two cases are examined. In the first case, one of the universities has the advantage of cost in teaching, while the other has the advantage of cost in research. In the second case, one of the universities has the advantage of cost in both teaching and research.

3.1. Case I: When Each University Has the Advantage of Cost in a Different Field

Suppose that University 1 has the advantage of cost in teaching, while University 2 has the advantage of cost in research, specifying the parameters as in what follows.

c_{t1}=1/2, c_{r1}=3/2, c_{t2}=1, c_{r2}=2/3,
$\underline{B}$=100 and α=1/10. (12)

Under the specification of (12), the reaction function of University 1 is depicted as the solid curve, while the one of University 2 is depicted as the dashed curve in Figure 5.

Non-cooperative solution in Figure 5, E_l, is a stable solution, and E_l is computed as

E_l ={821.11, 951.353} (13)

From this situation, suppose that the government intends to enhance the academic levels of the universities by introducing more competition into the higher education. This policy change is represented by the increase of α. Suppose that

c_{t1}=1/2, c_{r1}=3/2, c_{t2}=1, c_{r2}=2/3,
$\underline{B}$=100 and α=4/10. (14)

If the reaction functions under (14) are added to Figure 5, we obtain Figure 6. In Figure 6, the reaction function of University 1 is depicted as the *thick* solid curve, while the reaction function of University 2 is depicted as the *thick* dashed curve. Some part of the reaction function of University 1 is missing, since the Newton method failed in this part due to the improper selection of initial values.

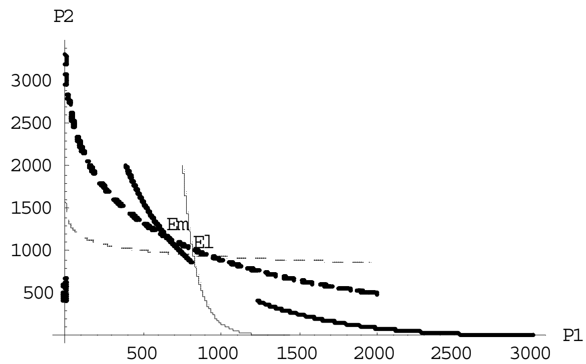

Figure 6: The Reaction Functions when α=1/10 and α=4/10: Differentiated Advantage I (E_l, E_m: Stable Solution)

Non-cooperative solution when α=4/10 in Figure 6, E_m, is a stable solution, and E_m is computed as

E_m ={649.386, 1170.21}. (15)

From the comparison between (13) and (15) it is clear that P_1*+P_2* increases as α increases. In this simulation, as competition intensifies, the stronger university becomes much stronger.

3.2. Case II: When One University Has the Advantage of Cost in Teaching and Research

Suppose that University 2 has the advantage of cost in teaching and research, specifying the parameters as in what follows.

c_{t1}=1, c_{r1}=2/3, c_{t2}=1/2, c_{r2}=1/3,
$\underline{B}$=100 and α=1/10. (16)

In this case, some may well predict that there does not exist Nash non-cooperative game solution, or even if there exists a game solution, it may be unstable. In what follows, it is shown that this prediction is false. Under the specification of (16), the reaction function of University 1 is depicted as the solid curve, while the one of University 2 is depicted as the dashed curve in Figure 7.

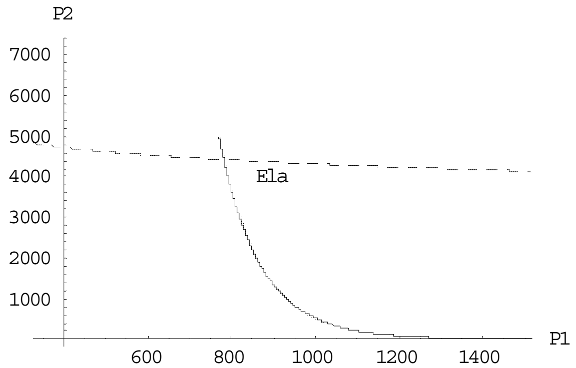

Figure 7: The Reaction Functions when α=1/10: Dominant Advantage II (Ela: Stable Solution)

Non-cooperative solution in Figure 7, E_{la}, is a stable solution, and E_{la} is computed as

E_{la} ={782.452, 4426.22} (17)

Note that E_{la} is a stable solution, even though University 2 has a dominant advantage of cost over University 1.

As in Case I, from this situation, suppose that the government intends to enhance the academic levels of the universities by introducing more competition into the higher education. This policy change is represented by the increase of α. Suppose that

c_{t1}=1, c_{r1}=2/3, c_{t2}=1/2, c_{r2}=1/3,
$\underline{B}$=100 and α=15/100. . (18)

If the reaction functions under (18) are added to Figure 7, we obtain Figure 8. In Figure 8, the reaction function of University 1 is depicted as the *thick* solid curve, while the reaction function of University 2 is depicted as the *thick* dashed curve.

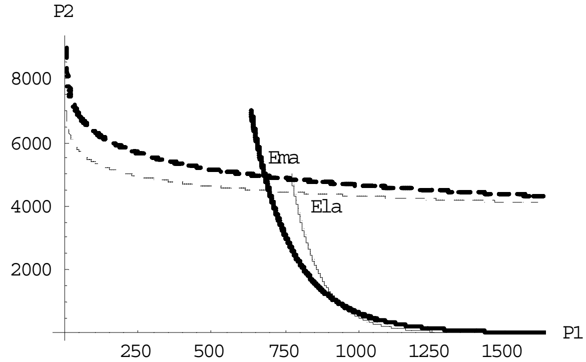

Figure 8: The Reaction Functions when α=1/10 and α=15/100: Dominant Advantage II (E_{la}, E_{ma}: Stable Solution)

Non-cooperative solution when α=15/100 in Figure 8, E_{ma}, is a stable solution, and E_{ma} is computed as

E_{ma} ={681.416, 4937.4}. (19)

From the comparison between (17) and (19) it is clear that P_1*+P_2* increases as α increases. As in Case I, in Case II, too, as competition intensifies, the stronger university becomes much stronger.
The conclusions in Cases I and II are robust when α is small, as shown in Fukiharu [2004].

3.3 Case III: When α is large

From the analysis in Cases I and II some may predict that when the two universities are differentiated in cost structure, the government can enhance the national academic levels simply by introducing more competition. A remark is in order in this prediction. When α is large the stability of Nash non-cooperative game solution is not guaranteed. In order to show this, suppose that

c_{t1}=1, c_{r1}=2/3, c_{t2}=1/2, c_{r2}=3/2,
$\underline{B}$=100 and α=8/10. (19)

Under the specification of (19), the reaction function of University 1 is depicted as the solid curve, while the one of University 2 is depicted as the dashed curve in Figure 9. Non-cooperative solution when α=8/10 in Figure 9, E_h, is the Nash game solution, and E_h is computed as

E_h = {969.052, 796.33}. (20)

From the slope of the two reaction functions, it is clear that E_h is an unstable solution.

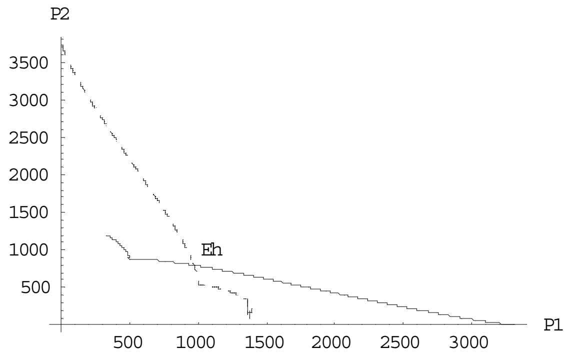

Figure 9: The Reaction Functions when α=8/10 (E_h: Unstable Solution)

Some may well argue that the instability is what the government desires since when only one of the universities remains the academic level in this case is greater than the sum of academic levels of the two universities at the unstable Nash solution. This argument, however, is not correct, since it violates the assumption of constant unit costs. When one university completely disappears from the education market, as is indeed feared in Japan, the other university must take care of all the students in the bankrupted university. In this case, the unit cost of teaching might become prohibitively high due to the campus capacity, etc. Thus, the assumption of constant unit costs is feasible only in the small variation for the comparative statics between *stable* solutions.

4. Conclusions

The aim of this paper is to analyze the government's educational policy in economic framework, extending the contribution by Bowen [1980], which constructed a simple one-university behavior model. In this paper, his model is extended to two-university model, and Nash-type non-cooperative game is constructed, following Fukiharu [2005], where the government provides university budget competitively. The focus is on the structures of Nash solutions when the government intensifies the university's competition for the university budget. Casual prediction may be possible: the Nash non-cooperative solution is stable and two universities prevail when the competition is not severe, and it will be unstable and one of the universities may disappear when the competition is quite severe. In examining this casual prediction, it is not easy to compute reaction functions analytically, so that simulation approach is adopted, by specifying unit costs of conducting research and teaching numerically. First, the identical unit costs model is examined. If the structure of the unit costs is identical between the two universities, it is shown that the Nash non-cooperative solution is stable and two universities prevail when the competition is not severe, and there is no Nash non-cooperative solution when the competition is severe. The interesting result in this simulation is that when the stable Nash-type game solutions exist, the resulting stable academic level of the university is independent of the government budgetary policy. Thus, it was shown that the mere intensified competition by the government cannot enhance the academic levels of universities. When the cost structure is different between the two universities, it was shown, that government can enhance the academic levels, by intensifying competition. The instability case emerges in this differentiated cost structure model. Thus, in order to enhance the national academic level by intensifying the competition for operating funds among universities, the government must check the cost structures among universities.

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