Modeling and Analysis of Information Systems Outsourcing based on Agent Systems

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***Abstract*—Information systems (IS) outsourcing can be classified into two typical but different patterns: conventional outsourcing and quasi-outsourcing. However, the diversity of the IS outsourcing decision whether firms are increasing, decreasing, or keeping their current outsourcing level is widely seen recently. Therefore, development of mathematical models depending on situations is required to describe and analyze the collaborations/relationships among firms in a general way. This paper deals with the analysis of profits/prices changes in formalizing of collaboration among agents and understanding of the IS outsourcing phenomena by applying a mathematical model based on agent systems. Up to now, two influential perspectives of outsourcing, that is, the TCE and the RBV have been both making a valuable contribution to understanding and explaining the complexities of outsourcing. However, we revealed that the outcomes of outsourcing can fluctuate inherently according to the degree of the collaboration between firms by our simulation studies. By assuming a firm agent produces goods by using support of another outside agent with several cost of labor usage, then the wealth of a firm agent bears some chaotic fluctuations depending on the rate of collaboration among agents. This finding is applicable to the cases where firms will procure services related to the IS activities from outside vendors in real society. Researchers and practitioners should keep in mind that it is a crucial issue of profits/prices changes according to the degree of collaboration between firms in their IS outsourcing decisions.**

***Keywords*—Information systems outsourcing, Collaboration, Agent systems, Simulation, Chaotic fluctuation.**

I. Introduction

RECENTLY, a large number of firms outsource their information systems (IS). In general, the IS outsourcing can be classified into two typical but different patterns: conventional outsourcing and quasi-outsourcing [1]-[8]. The former is based on a contract with an external vendor and so on. The latter means to set up their own IS subsidiaries which is defined as "a firm that is partially owned by the parent, but independently managed" [9]. Quasi-outsourcing is an alternative to complete insourcing and complete outsourcing, and is often adopted in the large-scale organizations.

However, the diversification of the arrangement of the IS subsidiary is widely seen. For instance, there have been many firms which strengthen or keep capital alliances between their IS subsidiary and external vendors, or completely sell it and dissolve the partnership. On the other hand, some firms forcing their IS subsidiaries to withdraw from external sales business, i.e., sales outside the parent company's group, or going further and internalizing the IS subsidiary back into the company again (so-called backsourcing).

The main contribution of this paper is to introduce a mathematical model for the analysis of collaboration and relationships among firms based on our reviewing the relevant early studies on the IS outsourcing. This paper deals with the analysis of profits/prices changes in formalizing of collaboration among firms and understanding of the IS outsourcing phenomena by applying a mathematical model based on agent systems. Our works will lead the way to the in-depth empirical study in the future.

This paper is organized as follows. In Section 2, we briefly review some previous arguments of the IS outsourcing. After reviewing the relevant literature on the IS outsourcing, we show a basic model for the analysis of profits/prices changes in formalizing of collaboration between two single firms based on agent systems and observe some examples of chaotic fluctuation in Section 3. In Section 4, we discuss the implications derived from the results of our simulation studies. Finally, in Section 5 we conclude by a summary of this paper and mention our future work.

II. Literature review on IS outsourcing

A. Transaction-based perspective

Transaction cost economics (TCE) posits that organizations insource when the maret costs are higher than internal governance costs [10]-[20]. Markets generally lead to smaller production costs, because of economies of scale obtained by suppliers/vendors. However, markets lead to higher transaction costs arising from three principal attributes of transactions: asset specificity, uncertainty, and frequency [11]-[16].

Asset specificity for the IS outsourcing has two aspects; for business of a client company supported by the developed information systems, and for technologies which external vendors utilize. If the business that a client company outsources is unusual, external vendors have to be familiar with the business so that the asset specificity will occur and increase on mainly human resources. Similarly, if technology used by external vendors is specific, it will be difficult to use the information systems for other purposes on the client company. Investment to these unusual assets causes a "fundamental transformation" [13]. Therefore, the transaction costs would increase.

Hence, if it is necessary to reduce the risk of opportunism resulted from asset specificity and to restrict the increase

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Manuscript received October 19, 2010; revised Novenber 6, 2010.

of transaction costs, insourcing or quasi-outsourcing would be selected. This is because a client company can wield an influence over its IS subsidiaries depending on its investment ratio under the operation of quasi-outsourcing (e.g. [1][2][5]).

B. Resource-based perspective

The resource-based view (RBV) of the firm based on the original work of Penrose [21] posits that organizations insource when a resource or capability is strategic so as to enable them to sustain competitive advantage [22]-[30]. It builds upon four properties of a strategic resource: economic value, rareness, imperfect imitability, and non-substitutability [22]. The RBV is important to the study of the IS outsourcing, as superior performance achieved in the IS activities related to external vendors would explain why such activities are performed internally.

Thus understanding of managerial resources as an advantage for the company is called "core competencies" in general today. Prahalad and Hamel [27][28] defined the core competence as "a combination of technologies and production skills which is based on the company's infinite product lines". This concept is understood more broadly today and is recognized as their own resources and abilities, which are hard to be imitated and implemented by other companies, as a source of the company's sustainable competitive advantage.

From the viewpoint of the RBV, competitive advantage of organizations can only be achieved through a focus on core competencies, the management of organizations have chosen to concentrate on what an organization does better than anyone else while outsourcing the rest. And if it is needed to be controlled strategically again, insourcing the businesses which were outsourced in the past will be reconsidered [1][2][5].

C. Diversity of IS outsourcing

The large number of studies of the IS outsourcing was published in the past [31]-[54]. Especially, in the previous study on the two patterns of the IS outsourcing, some focus on factors of the influence on its selection. For instance, Barthelemy and Geyer [1] classify the factors of the influence on the choice of either conventional outsourcing or quasi-outsourcing into internal and external factors. They focus on testing some hypotheses which are suggested based on the TCE approach, but they do not refer to the RBV arguments. The TCE and the RBV approach are treated as independent argument so far, but each theoretical perspective alone can not fully describe the phenomena of the IS outsourcing. Then there is a growing bodies of research on the recognition that the TCE and the RBV are complementary one another [49].

Other studies show that different effects and problems of the IS outsourcing caused from the different patterns. However, many studies found different effects of the IS outsourcing between conventional outsourcing and quasi-outsourcing. For instance, it is totally supported that "using new technology" effect of conventional outsourcing is higher than that of quasi-outsourcing. On the other hand, the issue is still under discussion whether the effects of "cost saving" and "improvement of planning and development of the IS skill" of these two patterns are different or not.

The Japan Information Processing Development Corporation made it clear that the companies setting up their own IS subsidiary now is only 8.3% as a whole in Japan [55]. However, depending on the scale of the company, its own IS subsidiary tends to be established. That is to say, 25.5% of the companies who have more than 1000 and less than 5000 employees are setting up their own IS subsidiary. In addition, it reaches the rate of 61.8% in the companies having more than 5000 employees. Moreover, this report reveals in detail that large-scale companies tend to establish their own IS subsidiary by spinning off their in-house department of information systems.

The results of the recent survey by *the Japan Users Association of Information Systems* [56] found that, among the requirements placed on the IS subsidiaries and external vendors by user companies, a company's planning and proposal capability for "restructuring business process using IT" has more high value than "reduction of development/operation cost" in Japan. Therefore, the fact that quasi-outsourcing shows greater familiarity with the parent company's work can be regarded as a significant advantage over conventional outsourcing. An empirical analysis by Hamaya [57] has also shown that, in outsourcing to the IS subsidiaries where there is a capital relationship, i.e., quasi-outsourcing, there is a tendency for the degree of review of business process at the parent company to increase significantly.

However, on quasi-outsourcing in recent years, a number of distinctive trends have appeared in management of the IS subsidiaries. A diversity of cases have been observed, such as: (1) capital alliance with an external vendor (majority or higher investment ratio), (2) capital alliance with an external vendor (less than majority investment ratio), (3) complete sale of the IS subsidiary to external vendor, (4) withdrawal from external sales, (5) integration back into the parent company (backsourcing), and so on [1][2][5].

Thus, the IS outsourcing tasks to outside firms is not always the best, and the problems to examine the collaboration based on mathematical models depending on the situations reveal as another important factors [58]-[63].

In the following section, we present a basic and general model to examine the profits/prices changes in formalizing collaboration among client companies (called firm agents) and suppliers/vendors agents (called outside agents).

III. The Model of Collaboration between Two Single Agents

Even though many conventional works related to outsourcing stress the contracting, but inherent in any act of outsourcing is the control loss, and a manufacture suffers from overseeing the delegated process. As a result, it is necessary manufactures frequently observe and update relationships with suppliers, even contracting on functionality and finished products.

Most of the outsourcing behaviors can be explained by linear models. But part of them are not always linear. Es-

pecially, research by Caballe et al. shows economies experiencing a process of financial development due to outsourcing are more unstable and chaos appears via a border collision bifurcation [62]. Also, Curries et al. discuss the chaos in the core-peripheral model under high transportation costs where workers move to other regions to improve real wages and purchasing of labor is unstable [63]. However, it is not still known whether the unstability is in the competition to avoid the cost for upfront payment and warranty clauses.

At first, we consider a small open economy where a firm agent manufactures goods by using resources provided by an outside agent as well as his own capital and labor. Then, it is founded that an increase in wealth raises the investment and the wealth time series bears chaotic fluctuation [64]-[66].

A. Description of the model

Even though the model treated in the paper are not restricted to production systems, but for simplicity we assume that a firm agent manufactures goods by using the equipment (called as capital in the following) and the labor force (called as labor in the following) provided by an outside agent. Here, we treat the case where there exits a single firm agent and a single outside agent. Since it is not necessary to distinguish outside agents, we simply define a single agent who provides labor for the production. In the definition of basic model for collaboration, we assume followings [67]-[77].

(1) Production by firm agent

We consider a small open economy in discrete time, and we denote the time period between two time stamps t and $t+1$ as the period t rather than instantaneous time. Because each agent is assumed to process information between two time stamps t and $t+1$ and make decision for the period t. A firm agent manufactures goods by using his own capital $K_1(t)$ and labor $L_1(t)$ in time period t. Beside $K_1(t)$ and $L_1(t)$, a firm uses the capital $K_2(t)$ and labor $L_2(t)$ provided by outside agent. Under these conditions, the output of products (goods) $y(t)$ is usually represented by the so-called production functions. There are several types of production functions, but we use the production function of the Cobb-Douglus type described as follows.

$$y(t) = A[K_1(t) + K_2(t)]^{\rho}[L_1(t) + L_2(t)]^{1-\rho}. \quad (1)$$

where A (a constant value) denotes the total factor productivity, and $\rho(0 < \rho < 1)$ is the elasticity of production (also a constant value).

(2) Purchase of capital and labor

A firm agent obtains the wealth $W(t)$ at the end of production in period t, and then besides the profit he makes the total investment $I(t)$ in period t for the production in period $t+1$ which is devoted to purchase both capital and labor from the outside agent. For the given level of investment, the optimal demand for the labor input $p(t)L_2(t)$ and for capital $K_2(t)$ in each period rise from the maximization of profit function subject to the budget constraint.

$$I(t) = K_2(t) + p(t)L_2(t). \quad (2)$$

where $p(t)$ is the market specific labor price for a unit of purchased labor. Now, we assume that the capital $K_1(t)$ and labor $L_1(t)$ prepared by the firm agent are determined at the beginning of whole production, and are not included in the investment in period t. We also assume that the capital $K_2(t)$ come from outside is to purchase in a long range, and is not affected by the market, even though the capital $K_2(t)$ still remains as variable to be determined to in the profit maximization.

(3) Optimal production

Then, the maximization of $y(t)$ in equation (1) is reduced to the problem to determine the capital $K_2(t)$ and the labor $L_2(t)$. By substituting the equation (2) into equation (1) and taking the derivatives with respect to the variable $L_2(t)$, we have the next relation.

$$L_2(t) = [B + (1-\rho)I(t)]/p(t), K_2(t) = -B + I(t). \quad (3)$$

$$B = K_1(t)(1-\rho) - \rho p(t)L_1(t). \quad (4)$$

By substituting the value of $L_2(t)$ into the equation (1), we obtain the vale for $K_2(t)$ which maximizes the function $y(t)$, but the expression is omitted here. It must be noted that the optimal value of the variable $L_2(t)$ includes the price $p(t)$, and depends on it. However, for simplicity we assume that the price $p(t)$ is known as a prescribed value here.

By using the optimal solution to maximize $y(t)$, we have the expression for the optimal value of production as follows.

$$y(t) = A[K_1(t) - B + \rho I(t)]^{\rho}[D + E\rho I(t)]^{1-\rho}, \quad (5)$$

$$D = L_1(t) + B/p(t), E = (1-\rho)/p(t). \quad (6)$$

(4) Time dependency of profits and credits

Let $W(t)$ be the wealth of a firm agent in period t. Since the wealth serves as a collateral for the loan with amount $L(t)$ where $L(t) \leq \alpha W(t)$ and α is the credit multiplier reflecting the level of financial development of the domestic economy. Then, the firm agent can invest in the productive project where the largest amount he can borrow is given as.

$$I(t) = W(t) + r\alpha W(t) = (1 + r\alpha)W(t), \quad (7)$$

where r is the interest rate. Hence, in period $t+1$ the firm agent receives the corresponding profits and pays the cost of debt $rL(t)$. Therefore, the dynamics of the wealth of firm is given by

$$W(t+1) = q[y(t) - r\alpha W(t)], \quad (8)$$

where q is the rate of profit with respect to the gross sales. By substituting equation (8) into the above equation, and also substituting $y(t)$ into equation (8), we have the following relation.

$$\begin{aligned} W(t+1) &= q[A[K_1(t) - B + CW(t)]^{\rho} \\ &\quad [D + E'W(t)]^{1-\rho} - r\alpha W(t)], \end{aligned} \quad (9)$$

$$C = \rho(1+\alpha), E' = (1-\rho)(1+\alpha)/p(t). \quad (10)$$

Even though we use the above equations to evaluate the change of profit between periods t and $t+1$, but if the interest rate r is

greater than the rate of profit obtained by the production , the firm agent feels no incentive to borrow up to the credit limit and use his own current wealth $W(t)$ for production. Then, the firm agent selects productive activity rather than credit. These situations will occur if the specific value W^m of W satisfies the relation $y(t)-r\alpha W(t) = rW(t)$. Then we obtain the value W^m which satisfies,

$$q[A[K_1-B+CW(t)]^{\rho}[D+E'W(t)]^{1-rho}-r\alpha W(t)] = rW(t). \quad (11)$$

This is so because, even if an increase in wealth raises the investment, the amount of invested wealth depends negatively on the price $p(t)$.

By using the value W^m, including the the case where $W(t) \leq W^m$ is satisfied, the asymptotic behavior of wealth is thus determined by the iteration of the following functions.

$$W(t+1) = \begin{cases} q[y(t) - r\alpha W(t)]; 0 \leq W(t) \leq W^m; \\ rW(t); W(t) > W^m \end{cases} \quad (12)$$

B. Chaoticity result for $W(t)$

In the following, we show the chaoticity result for the wealth time series $W(t)$. Since the functional form for $W(t)$ is complicated, it is hard to show analytically the chaoticity for $W(t)$, and then we use the bifurcation diagram for $W(t)$ depending on the parameter α based on simulation studies.

Fig.1 shows an example for the time series $W(t)$ with $\rho = 1/3, A = 1.5, L_1 = K_1 = 100, r = 1.02, \alpha = 58$. Fig.2 shows the bifurcation diagram for $W(t)$ depending on the parameter α. We also show the maximum Liapunov exponent L_P for $W(t)$ with the same condition where the embedded dimension is two and the time delay is one as shown in Table 1. The wealth time series $W(t)$ converges to a single point, namely, the stable equilibrium, when the parameter α is less than $\alpha_B = 10$. A periodic-doubling bifurcation of the equilibrium occurs as α increases over α_B. For α just over α_B, the time series alternates between a stable two-cycle. Then, we see the two cycle splits into a four-cycle, which then turn into the band of Li-Yorke chaos when $\alpha > 56$. Further we see the large window of the stable three cycle when $\alpha > 61$.

TABLE I
MAXIMUM LIAPUNOV EXPONENT FOR $W(t)$ DEPENDING ON α ($\rho = 1/3, A = 1.5, L_1 = K_1 = 100, r = 1.02$).

α	5	10	20	50	60	80	100
L_P	-0.21	-0.32	-0.12	0.29	0.01	-0.01	-0.01

C. Chaotic fluctuation induced by $p(t)$

Even though the wealth time series $W(t)$ is stable and has a single value if $\alpha < \alpha_B, \alpha_B = 10$ and with constant value of price $p(t)$, but $W(t)$ becomes to be chaotic if $p(t)$ is chaotic. Such sources of chaoticity for $p(t)$ is not discussed here, and we only show an example of rise of chaoticity in $W(t)$. Fig.3 shows an example of wealth time series $W(t)$ with $\alpha = 5$

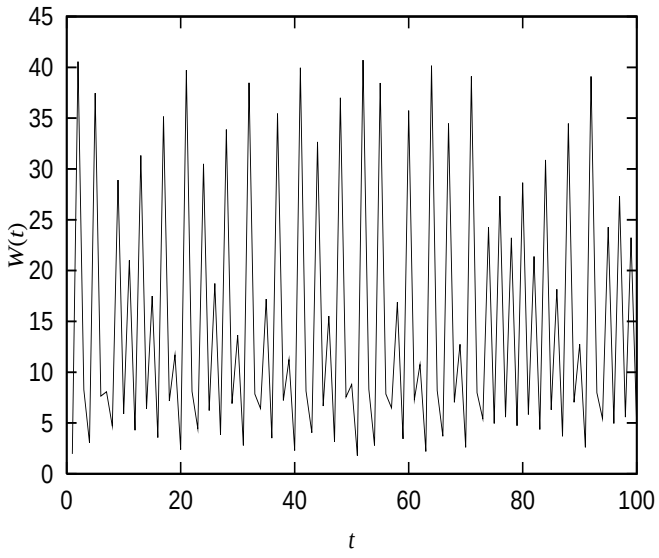

Fig. 1. An example of time series $W(t)$ ($\rho = 1/3, A = 1.5, L_1 = K_1 = 100, r = 1.02, \alpha = 58$).

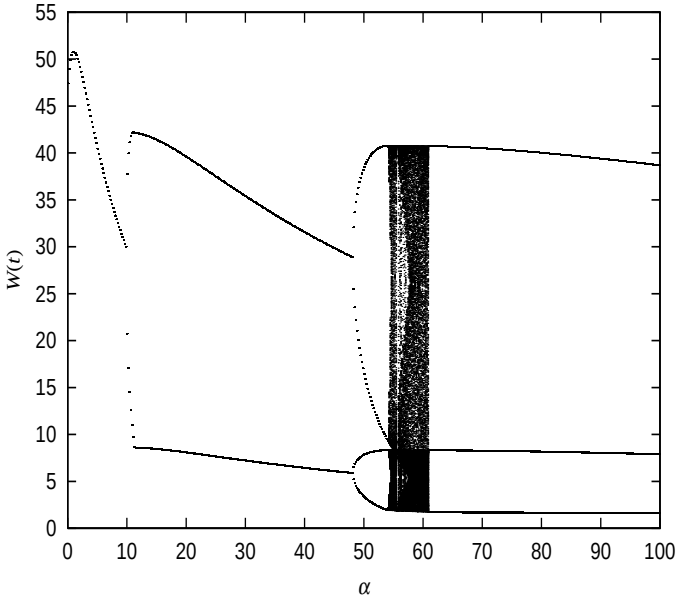

Fig. 2. Bifurcation diagram for $W(t)$ depending on α ($\rho = 1/3, A = 1.5, L_1 = K_1 = 100, r = 1.02$).

before and after time point t_A after which the time series $p(t)$ bears chaoticity. As is seen from Fig.3, the time series $W(t)$ becomes no more stable after t_A. Then, we must note that chaoticity of $W(t)$ is induced by increasing α greater than α_B, as well as the rise in chaoticity in $p(t)$.

The issue of whether the time series $W(t)$ keeps stability is closely related to the labor price $p(t)$. Most of papers dealing with the outsourcing address the contract writing and therefore fixed and long term price setting [1]-[8]. However, we can observe in real society, many firms change purchasing scheme in production system from ordering assemblies (outsourcing) again back to their own manufacturing (insourcing). Most

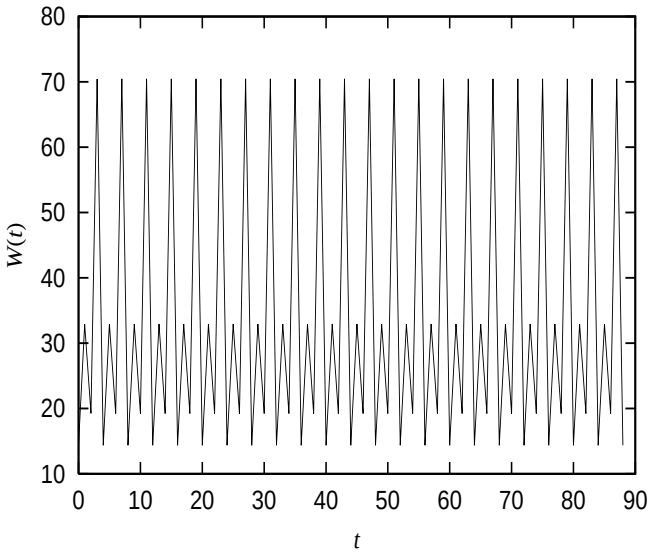

Fig. 3. An example of rise of chaoticity in $W(t)$ with $\alpha = 5$ due to chaoticity in $p(t)$ ($\rho = 1/3, A = 1.5, L_1 = K_1 = 100, r = 1.02$).

of the reasons to change the purchasing scheme are related to the higher labor price $p(t)$ provided by an outside agent. Therefore, we must also observe how the change of $p(t)$ affects the stability of $W(t)$. We need to look up about that in future, but we emphasize the chaoticity of $W(t)$ induced by $p(t)$ [64]-[66].

As is seen, in the collaboration between two agents if the parameter α is restricted to be small such as $\alpha < \alpha_B$, the wealth time series $W(t)$ is stable. However, the stability is attained on the basis of stationarity (constant value) of labor price $p(t)$ throughout manufacturing. Note that particular cases may occur where the labor price is no more stable and determined by the competitive edge among firm and outside agents. If we assume there exist multiple firm agents and outside agents, then firm agents tend to search cheaper labor price across outside agents. Moreover, if firm agents seek cheaper labor price, then outside agents react to purchasing by changing (decreasing) the labor price. However, the demand from firm agents may be concentrated on a certain outside agent, then the labor price will be raised to adjust the imbalance in the supply-demand framework. Then, the optimal labor price is selected and updated through a competitive manner.

This implies the necessity that we will deepen the consideration of the more complex structure by means of the extending this basic model into collaboration among multiple agent systems by the network structure [72][77].

IV. Implications for IS outsourcing management

This paper added to understanding of the IS outsourcing phenomena by applying the mathematical model based on agent systems. We indicated that even though any uncertain parameters are not included in the expression that describes the relations between agents fundamentally, the wealth time series bears chaotic fluctuation by our simulation studies. This finding is applicable to the cases where firms will procure services related to the IS activities from outside vendors.

Today, many managers are aware of the characteristics of their outsourcing portfolio and/or level. Two influential perspectives of outsourcing, i.e., the TCE and the RBV have been both making a valuable contribution to understanding and explaining the complexities of outsourcing. These theories can provide managers with the rational framework for their outsourcing decisions.

However, we have revealed that the outcomes of outsourcing vary according to the degree of the collaboration between firms based on the model analysis. This implication is very important both in theory and practice. Researchers and practitioners should keep in mind that it is a crucial issue of profits/prices changes according to the degree of collaboration between firms in their IS outsourcing decisions.

V. Conclusion and future research

Mathematical models are needed for the analysis of collaborations among firms, especially in the IS outsourcing.

This paper dealt with the analysis of profits/prices changes in formalizing of collaboration among agents and its applications, and we revealed that the outcomes of outsourcing can fluctuate inherently according to the degree of the collaboration between firms. By assuming a firm agent produces goods by using support of another outside agent with several cost of labor usage, then the wealth of a firm agent bears chaotic fluctuation depending on the rate of collaboration among agents.

This finding is applicable to the cases where firms will procure services related to the IS activities from outside vendors in real society. Researchers and practitioners should keep in mind that it is a crucial issue of profits/prices changes according to the degree of collaboration between firms in their IS outsourcing decisions.

For future research, the model developed in this paper will be extended to multi-agent systems under the collaboration in a network structure, and we will show the control (suppression) scheme for the chaotic fluctuation by using the deterministic decision on input and pricing. In addition, we will examine the real examples of collaborations and usefulness of suppression of fluctuations in labor price.

Furthermore, we need to consider other factors assumed to affect the IS outsourcing decision-making [78][79]. For instance, finance-related effects of the capital policy among firms will be effected from the institutional environment, such as corporate law, acts of protecting personal information, risk management [80]-[84]. And, firms relationship analysis is the IS outsourcing will be one of the most important issues [85]-[96].

Acknowledgment

The authors would like to thank the editor and the three anonymous reviewers for all their helpful suggestions. We are grateful to the Ministry of Education, Culture, Sports, Science and Technology for providing funding for this research under Grant-in-Aid for Exploratory Research, 21510171, 2009, and

the Japan Society for the Promotion of Science for providing funding for this research under Grant-in-Aid for Scientific Research (C) 20530332, 2009.

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