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Software Vendors' Investment in Unobservable Attributes of Product Quality: An Economic Approach for Enterprise System Products

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Our aim was to study software vendors' investment in the quality attributes of an enterprise system that are unlikely to be evaluated by customers when they make a decision on which system to purchase. Unique characteristics of the domain of the enterprise system market distinguish it from the domain of traditional product markets. Using game theories, we developed several models showing the existence of an equilibrium in vendors' investment under two different pricing mechanisms. After finding that an investment equilibrium could exist, we were able to obtain optimal levels of investment in the unobservable quality attributes of an enterprise system.

Keywords: Enterprise systems, enterprise software, investment in quality, price and quality.

1. Introduction

The size of enterprise system[1] market has been growing. According to the Gartner Group of Boston, a survey of 1,400 chief information officers worldwide showed that the budget for firms' IT spending in 2006 has increased by an average of 2.7%, and that the growth rate is higher than

[1]An enterprise system is defined as a commercial software package that is installed and customized in an organization, and that takes responsibility for the information systems of the organization, including providing information for decision making, bridging employees for communication, and so on. In our definition, an enterprise system includes the groupware portal, knowledge management, ERP software, customer relationship management, and sales force automation. In this paper, the term *enterprise software* is used equivalently with the term *enterprise system*.

the rate in 2005 by 2.5% (Loizos, 2006). Because a major proportion of the IT budget in a firm is spent on enterprise systems, markets for these systems continue to advance. A discussion of enterprise systems is therefore particularly meaningful in the present market context.

With the increase in competition among vendors of enterprise systems and advances in software technologies, the demand for enterprise systems of high quality continues to increase. However, software vendors face a dilemma when they decide to invest for unobservable quality attributes. Because characteristics of enterprise systems are unique in a respect, some quality attributes of the system are unable to be evaluated by customers until the system is operated and used for a while. For those quality attributes, software vendors have a limited incentive to invest in the software development process. Such an investment would increase the cost of developing the packaged software in the short term but could decrease the cost of customization and maintenance in the long term.

The aim of this paper is to find equilibrium in software vendors' investment for the unobservable attributes of software quality and to identify optimal levels of investment in the research domain for enterprise software[2] vendors. Although much research has investigated the investment in R&D or production lines to ensure the quality of products, prior analyses of traditional product industries cannot easily be applied to the economy of enterprise software because of the different value chains and business mechanisms of the industry. The present study could provide software vendors with guidelines when they make decisions on the level of investment in the development

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[2]In this paper, the term *enterprise software* is used equivalently with the term *enterprise system*.

process for the quality of packaged software, and would provide researchers with a better understanding of economic activities in the domain of enterprise software industries.

To achieve our goal, we first show that an equilibrium can exist when investing in the unobservable attributes of software quality by using game theory. Second, we solve our model in two different economic contexts—the competitive market and the monopoly market. We assume that in the competitive market, the price of a vendor's product is not influenced by the level of investment in the software development process and in quality, and that in the monopoly market, the price is affected by the level of investment in the process and by the quality of the product. Each enterprise IT application is in a given stage of its product life cycle, and its market situation will be different. In this regard, studying the level of investment as a proxy of the quality of enterprise software in both the competitive market and the monopoly market will provide software vendors with useful insights when making critical decisions in the quality of products.

We found that the software vendor's best strategy is to invest in the unobservable quality attribute of enterprise systems even if customers are to be uninformed about the quality when they make a decision of purchasing. After, from this finding, we see that the vendor has incentive to invest for the unobservable quality of enterprise systems, we get optimal investment levels under two different pricing mechanisms.

The following section describes the research domain, which includes the difference between the enterprise software economy and the traditional product economy, and reviews prior studies on the relationship between price and quality when customers are lacking complete information about product quality. Section 3 shows the existence of an equilibrium for investment in the unobservable attributes of quality. Section 4 develops several simple models to get optimalized invemtment levels under both the competitive market and the monopoly market, and Section 5 discusses the results in our study. Section 6 concludes the discussion.

2. Background on the Research Domain and Assumptions

2.1. Trades Between Enterprise Software Vendors and Customers

Enterprise software companies have value chains that differ from traditional product companies in some respects. In general, a software vendor produces packaged enterprise software through the development process. Next, the vendor contracts with its customers to purchase the package. The contract specifies the use of the software license, the delivery of customization, and maintenance. For example, when a software vendor sells knowledge management systems to a customer, the vendor offers the use of the software license for certain periods of time, undertakes the project of installation and customization, and provides maintenance services. The customer pays for those selling components.

In this paper, we focus on the quality of an enterprise system, although other important factors, such as advertising, the reputation of the brand, and customer relationships, can also affect a vendor’s performance. When a customer decides whether to purchase an enterprise system from a software vendor and adopt it, the quality of the packaged software is a critical factor that determines that decision. The customer needs to confirm whether the quality of an enterprise system is at least as great as the level of need before the decision is made, but some quality attributes are hardly measured and evaluated by the customer before they use the system. The next section describes the problem of the unobservable quality.

2.2. The Quality of Enterprise Systems and Unobservable Attributes of Quality

The quality of an enterprise system is asymmetric information because customers have limited information on various quality attributes of the enterprise software and only software vendors know its true quality. In the past, discussions of the quality of enterprise software referred its performance and reliability. However, with advances in software technologies, diverse quality attributes now determine the overall quality of a software product. According to literature from the 1980s, reliability was emphasized as the most important indicator of software quality (Basili and Pericone 1984). In contrast, in a 1995 study, quality referred to software with a high level of capability and usability, leading to overall customer satisfaction (Kekre et. al., 1995). Other research found that customers in North America and in Japan had different preferences regarding the desirable quality attributes of e-commerce software products (Krishnan and Subramanyam, 2004). These prior findings indicate that the quality attributes of enterprise systems that matter today include those of functionality or capability, reliability, usability, modifiability, performance, maintainability, and security.

The customer's choice becomes problematic in product selection, because the purchaser is able to evaluate only a portion of all the quality attributes, such as its functionality, performance, and usability, which in this paper are referred to as *observable quality attributes*. Other quality attributes, such as security, modifiability, and reliability, which are referred to here as *unobservable quality attributes*, are not easy for the customer to evaluate before running the enterprise system in that organization, but such attributes would influence customers' the utility function. A customer who is satisfied with the performance, usability, and functionality of an enterprise system product may encounter troubles if its unobservable quality attributes are inferior. That is, if the modifiability of the packaged software is poor, much more time and effort would be required to customize it; if its security attributes are poor, the customer's system would be very vulnerable, which might contribute to financial loss via security attacks; and if the reliability attribute is inferior, the customer could experience many system errors.

Here, we assume that such unobservable qualities are exclusively determined by the amount which a vendor invests for the quality in the software development process, and that the investment includes the budget and effort. This assumption is reasonable because more resources are required to enhance those quality attributes of the software. Observable quality attributes of the software must also be determined by the level of investment, but a certain level is definitely necessary to meet standards required by the market or by the customers themselves. Because the incentive for investing in observable quality attributes is quite strong, we will not focus on the level of investment in observable attributes. Rather, we will focus on the level of investment in unobservable quality attributes, assuming that vendors have a fixed level of investment in the observable quality attributes.

2.3. Software Quality and Investment in the Software Development Process

For the software vendor, the software development process is similar to the production process of traditional product companies. Just as greater investment in product lines and raw materials can lead to a better-quality product in the traditional market, so is greater investment in software development likely to lead to higher-quality enterprise software. In our model, we assume that the relationship between the investment in software development and the quality of packaged software is positive and linear. One difference between the software development process and the typical production process is that the cost of software development does not increase with the quantity of sales, because the reproduction costs for software are nearly zero. Compared with the cost of developing packaged software, the cost of making CD packages is very small, which is one of most distinguishing characteristics of digital products.

2.4. The Problems of Enterprise Software Vendors and Customers

From the perspective of the enterprise software customer, purchasing and adopting an enterprise system are quite critical decisions that may either lead the firm's IT spending to be wasted or lead to successful innovation in the firm. However, selecting an enterprise system product is not an easy decision because the true quality of an enterprise system is private information for the software vendor, and the customer would have made the purchase decision before beginning to fully adopt the system. In addition, once an organization chooses a software vendor with a specific enterprise system product, she might have to use the enterprise system for several years.

Software vendors invest in product quality in order to meet the expectations of their customers. However, during the development process, the software vendor has a limited incentive to invest in the quality attributes of packaged enterprise systems, which customers are unlikely to have evaluated before purchasing a system. On one hand, having software with unobservable attributes of high quality would not help in the customer's decision, so the vendor might not want to invest in those attributes. On the other hand, having a high quality in the unobservable attributes would benefit the vendor during the customization and maintenance processes. For instance, the attribute of a high level of modifiability would enable the vendor to customize the software more effectively in response to a customer's request, thus saving time and effort, and a high level of reliability and security would reduce maintenance costs and prevent potential breaches of security. From a long-term perspective, a high level of investment in enhancing the overall quality would benefit vendors through a good brand reputation and a high level of customer satisfaction. In summary, the true quality of an enterprise system, particularly of its unobservable quality attributes, results in asymmetric information, and it affects the software vendor's costs in providing customization and maintenance services.

2.5. Price and Quality

Our model will be examined under different pricing mechanisms. We assume that, under the competitive market, the price of an enterprise system is mainly determined by the perceived quality attributes instead of the true quality or amount of investment in package development. Because vendors have an incentive to lie about the unobservable quality attributes, customers may not believe what vendors have to say about those quality attributes. On the other hand, if a software vendor holds a monopoly, the quality could increase or decrease, depending on the vendor's costs in developing the software for its quality. Thus, in that case, we could see the price being used as an expensive signal of the true quality.

In general, the price of a product is determined by its quality, advertising, packaging, and brand name reputation (Alpert, Wilson, & Elliott, 1993; Gardner, 1971). Among the factors identified in the literature, here we focus on quality, particularly whether the quality perceived by the customer matters or the true quality of the product matters. The relationship between price and the quality of a product has been studied by a number of researchers (Gabor & Grander, 1966; Gardner, 1971; Stiving, 2000). Here we compare the firm's profits at the optimal levels of investment in the software development process when the price reflects only the perceived quality and when the price conveys a vendor's private information about the true quality of the product.

3. Model

3.1. Basic Model

A software vendor sells its enterprise system products to customers. The vendor has already invested in observable quality attributes that are demanded by customers in the market, and the vendor must decide on the amount it wishes to invest in unobservable quality attributes. The customers evaluate the product, but their evaluation is based only on their perceived quality of the enterprise software. When a customer enters into a contract with the software vendor, the customer specifies customization of the enterprise software, and the customizing work will be delivered in a customization project. After the customization project and the beginning of operations, the software vendor provides maintenance services. The price of the license fee, the delivery of customization, and maintenance services are agreed on after negotiations when the customer decides to purchase the enterprise system. The price of the system, p, in this model includes the prices of the license fee, the delivery of customization, and the maintenance.

A customer's utility function, W, is determined by the amount of investment for unobservable quality attributes s, the quantity q, and price p. The range of s is from 0 to S. Here, we assume that the investment for observable quality attributes are already invested and given. The customer's utility function W represented by the function

$$W(s,q) = sq - pq \,. \qquad (1)$$

The utility function $W(s,q)$ is increasing and concave for each $s \in [0, S]$.

$$W(0,q) = 0; W_1(s,q) > 0, W_{11} \le 0 \text{ for all } s$$

Numbered subscripts to the functions denote partial derivatives with respect to the corresponding argument.

The software vendor's objective will be to maximize its profit. The profit function, π, is determined by its revenue and costs. The costs include costs in software development process and costs in the delivery of customization, and costs in providing maintenance services. The vendor's profit is represented by the function

$$\pi(q,s) = pq - K(s)q - s/N \,, \qquad (2)$$

where s is the amount of investment on software development for unobservable quality attributes, N is the number of customers, $K(s)$ is a cost function that refer to the amount of costs occurred during customizing for customer modification requests and providing maintenance services. A vendor's minimum investment on software development $s_0 = 0$ indicates that the vendor invests on software development only for observable quality attributes, which means that its enterprise software has extremely poor quality in unobservable attributes, which lead to vendors' maximum cost in customization and maintenance.

The customizing and maintenance cost function *K(s)* are decreasing and concave for $s \in [0, \infty]$.

$K(0) = k; K_1(s) < 0, K_{11} \le 0$, for all $s \ge 0$

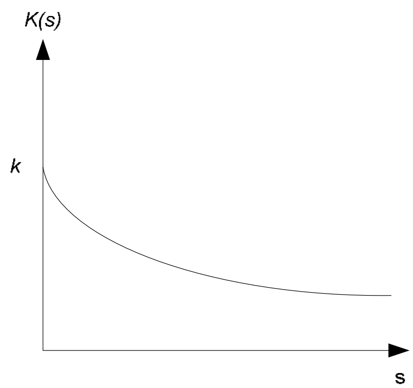


Figure 1. the cost function of modification and maintenance

3.2. Fishman and Simhon's Quality Investment Game

Fishman and Simhon (2000) proved that an investment equilibrium does not exist if buyers are uninformed about quality. In this section, we intend to explain why Fishman and Simhon's proposition cannot be applied to our model by using a game similar to their quality investment game.

Assume there is a software vendor who sells enterprise systems and there are identical buyers. Given a required level of observable quality attributes of the enterprise system, the vendor must decide whether to invest in the unobservable quality attributes, which require the investment of s. We will call the system low quality when the vendor does not invest in unobservable quality attributes and high quality when the vendor invests s for that. The values of high and low quality for customers are V_H and V_L, respectively, $V_H > V_L$.

The objectives of the vendor and customer will be to maximize profits and consumer surplus, respectively. Let's assume that a Bayesian Nash equilibrium exists. In the equilibrium, p_L and p_H denote the equilibrium price at low and high quality, respectively, and q_L and q_H are quantities demanded at price p_L and p_H, respectively, $p_L < p_H$. K_L and K_H are the unit costs of customization and maintenance services with a low and high quality product, respectively, $K_L > K_H$. Then the vendor's profits from a low- and high-quality product will be $p_L*q_L - K_L$, and $p_H*q_H - K_H - s$, respectively. Because p_L and p_H must be optimal for the vendor, the following inequalities should be satisfied:

(a) $p_L * q_L - K_L * q_L \geq p_H * q_H - K_L * q_H$

(b) $p_H * q_H - K_H * q_H - s / N \geq p_L * q_L - K_H * q_L - s / N$

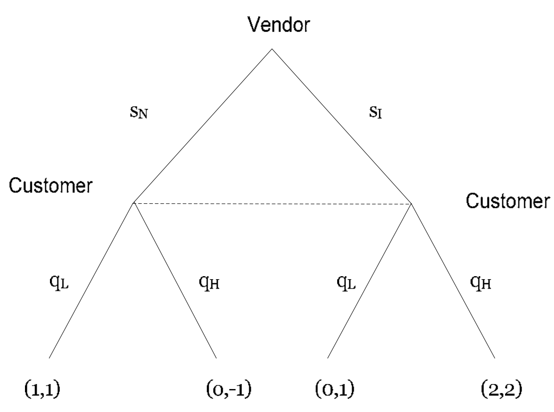
The left formulas in (a) and (b) represent profits at the optimal price for the vendor of a low- and high-quality product, respectively. Fishman and Simhon (2000) proved their proposition by showing that the profit of a low-quality firm is at least as great as that of a high-quality firm. In their model, the cost of the high-quality firm, c_H, is always greater than that of a low-quality firm, c_L, so the inequality $p_L*q_L - c_L*q_L \geq p_H*q_H - c_L*q_H \geq p_H*q_H - c_H*q_H$ supports their proposition. However, for enterprise software, K_L is greater than K_H. $p_H*q_H - K_L*q_H$ in (a) could be less than

$p_H*q_H - K_H*q_H - s$, depending on K_H and s. Therefore, we argue that, in the domain of the enterprise software market, an investment equilibrium could exist even if buyers are uninformed about quality. In the following two sections, we will show the existence of an investment equilibrium using game theories.

3.3. An Exapmle in the Competitive Market

As shown in Figure 2, consider the following two-stage game of imperfect information (Kreps & Wilson 1982, Gibbons 1992).

1. The vendor chooses whether to invest in the unobservable quality attributes of its enterprise software. s_N refers to "not invest" and s_I refers to "invest."
2. The customer cannot observe the vendor's action regarding the enterprise software.
3. The customer chooses the quantity of enterprise software between low quantity (q_L) and high quantity (q_H).



(a) Extensive Form

		Customer	
		q_L	q_H
Vendor	s_N	(1, 1)	(0, –1)
	s_I	(0, 1)	(2, 2)

(b) Normal Form

Figure 2. A dynamic game of imperfect information between the vendor and the customer

In this game, we assume that the vendor does not change the price of the enterprise system because the competition among competitors is too high. The payoff (a, b) in Figure 2 represents the payoff for the vendor and the customer, respectively. The payoffs in Figure 2 are determined by the following rules, which are based on our model in Section 2.1.

Vendor's payoffs:

- $\pi(s_I, q_H) \geq \pi(s_N, q_H)$ and $\pi(s_I, q_L) \leq \pi(s_N, q_L)$
- $\pi(s_I, q_H) \geq \pi(s_I, q_L)$ and $\pi(s_N, q_H) \leq \pi(s_N, q_L)$

Customer's payoffs:

- $W(s_I, q_i) \geq W(s_N, q_i)$, for i = {L, H}
- $W(s_I, q_H) \geq W(s_I, q_L)$ and $W(s_N, q_H) \leq W(s_N, q_L)$

Proposition 1. [s_I, (q_L, q_H)] is the Subgame–Perfect Nash Equilibrium in the game of the enterprise software vendor and the customer. The strategy [s_I, (q_L, q_H)] denotes that the customer will choose low quantity following no investment by the vendor and high quantity following investment by the vendor.

Proof. In the Nash Equilibrium (s_N, q_L) and (s_I, q_H), neither the vendor nor the customer has any incentive to deviate from the equilibrium. But because the vendor knows the customer's best response to each of the vendor's actions, the vendor will choose s_I rather than s_N (payoff 2 > payoff 1). ■

Proposition 1 implies that even if customers are uninformed about unobservable quality attributes of an enterprise system, a software vendor may reach equilibrium by investing in those unobservable quality attributes in a competitive market.

3.4. An Exapmle in the Monopoly Market

In this game, we assume that the vendor uses the price of enterprise software as a signal of its quality after choosing whether it will invest in the unobservable quality attributes. Customers will perceive the quality of the enterprise software from its price. As shown in Figure 3, consider the following two-stage game of imperfect information between an enterprise software vendor and a customer (Spence, 1973):

1. The vendor invests in the unobservable quality attributes of the enterprise software with a 50% probability and does not invest with a 50% probability.
2. The vendor observes s_i, $i = \{L, H\}$, and then chooses a message p_i, $i = \{L, H\}$.
3. The customer observes p_i and then chooses an action q_i, $i = \{L, H\}$.

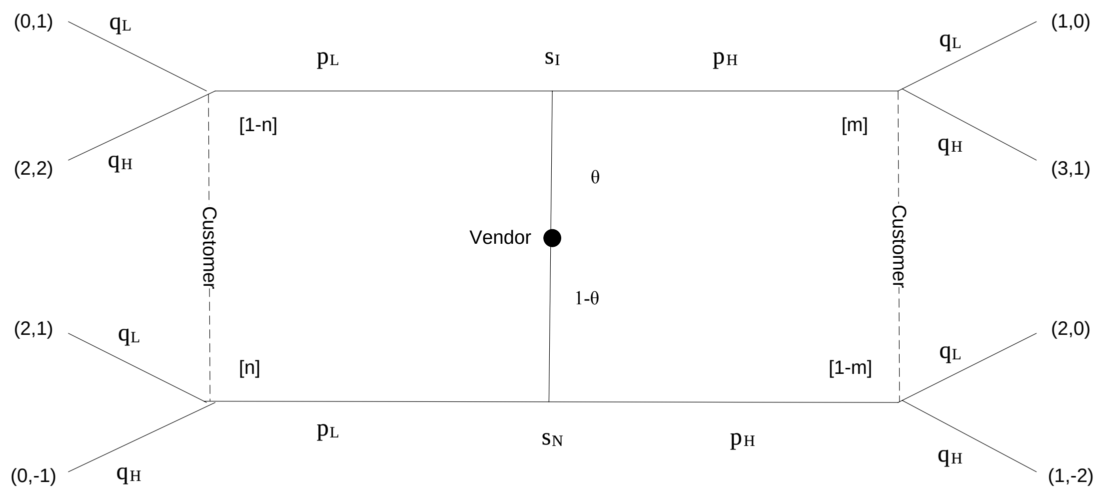


Figure 3. A signaling game between the vendor and the customer

Similar to Section 3.3, the payoffs in Figure 3 are determined by the following rules, which are based on our model in Section 2.1.

Vendor's payoffs:

- $\pi(s_I, p_i, q_L) \leq \pi(s_N, p_i, q_L)$ and $\pi(s_I, p_i, q_H) \geq \pi(s_N, p_i, q_H)$, for i ={L, H}
- $\pi(s_i, p_L, q_j) \leq \pi(s_i, p_H, q_j)$, for i ={I, N} and j ={L, H }
- $\pi(s_I, p_i, q_L) \leq \pi(s_I, p_i, q_H)$ and $\pi(s_N, p_i, q_L) \geq \pi(s_N, p_i, q_H)$, for i ={L, H}

Customer's payoffs:

- $W(s_I, p_i, q_j) \geq W(s_N, p_i, q_j)$, for i ={L, H} and j ={I, N}
- $W(s_i, p_L, q_j) \geq W(s_i, p_H, q_j)$, for i ={I, N} and j ={L, H }
- $W(s_I, p_i, q_L) \leq W(s_I, p_i, q_H)$ and $W(s_N, p_i, q_L) \geq W(s_N, p_i, q_H)$, for i ={L, H}

The purpose of applying our model to this signaling game is to examine whether an equilibrium exists when the vendor invests in the unobservable quality attributes and increases the price.

Thus, we will study the separating strategy of the vendor, in which the vendor plays p_H with s_H and plays p_L with s_L..

Proposition 2. The strategy [(p_H, p_L), (q_L, q_H), n = 1, m = 1] is a separating perfect Bayesian Equilibrium in the signaling game when the vendor uses the price of the enterprise system as a signal of the unobservable qualities. (p_H, p_L) denotes that the vendor sends the message of p_H with s_I and the message of p_L with s_N, and (q_L, q_H) denotes that the customer plays q_L, responding to p_L, and plays q_H, responding to p_H. m and n are the beliefs of the customer.

Proof. If the vendor plays the separating strategy (p_H, p_L), then the customer's beliefs must be n = 1 and m = 1, so the best response of the customer will be (q_L, q_H). At the equilibrium, the vendor has no incentive to deviate because its payoffs will not be better off by deviating from the equilibrium. Thus, the strategy [(p_H, p_L), (q_L, q_H), n = 1, m = 1] is a separating perfect Bayesian Equilibrium in the signaling game. ■

Proposition 2 implies that there could be an equilibrium when the vendor invests in unobservable qualities and increases or decreases the price, depending on its investment. That is to say, the vendor may have an incentive to invest in unobservable qualities.

4. Optimal Levels of Investment for the Unobservable Quality of Enterprise Systems

In the previous section, we developed a model and found that investment equilibrium could exist in both two different pricing mechanisms of enterprise systems. Since we found that software vendors may have an incentive to invest in the unobservable quality of enterprise systems, in this section, we intend to find optimal levels of investment for unobservable qualities from the perspective of the software vendor.

4.1. A Simple Model of the Software Vendor in the Competitive Market

In this case, I assume that the price of enterprise systems is exclusively determined by customers' perceived quality in the competitive market because customers know that strong incentive to exaggerate the quality and would not believe its talk about the quality attributes that can hardly evaluated. Thus, the vendor could not increase the price though it invested for the unobservable quality, so the price is fixed in this case.

Among potential customers, only those who are satisfied with the price and their perceived quality of the enterprise software will make contracts that specify the scope of customization and maintenance and purchase it. We assume that of a customer's requests specified in their contract will be delivered regardless the quality of the enterprise system, so the quality will not affect the customer's preference. Then, the customer's preference is only determined by the customer's value of the enterprise system v and the price p and the quantity of sales $q(p)$ will be equal to v - p.

$$q(v, p) = v - p \qquad (3)$$

, where v is uniformly distributed in $[0,V]$.

We use a simple form of $K(s)$ represented by the function

$$K(s) = \frac{k}{1+\beta s} \ , \qquad (4)$$

where k refers to the vendor's cost of delivering customization and maintenance to customers when software is designed without any consideration of unobservable quality attributes, and β refers to the degree of vendor's technical capability that may determine the efficiency of investment for the quality. Alternative conceptual definition of k is the amount of works for customization and maintenance.

Then, the vendor's profit will be

$$\pi(p,s) = p(v-p) - K(s)(v-p) - s/N = p(v-p) - \frac{k}{1+\beta s}(v-p) - s/N. \quad (5)$$

From Equation (5), we can get the optimal level of investment on software development process for invisible quality attributes.

Proposition 3. When the price of an enterprise system product has a positive linear relationship with the customers' perceived quality, the optimal level of vendors' investment for the unobservable quality of the enterprise software is

$$s^* = -\frac{N}{\beta} + N\sqrt{\frac{k}{\beta}(v-p)}, \quad (6)$$

Proof. From the first-order conditions of Equation (5) with s, we can get Equation (6).■

In this model, the price p is given, not variable because we assume a competitive market where a firm is not able to affect the market price.

4.2. A Simple Model of the Software Vendor in a Monopoly Market

In this case, the vendor uses the price of an enterprise system as a signal of the product quality. The vendor intends to convey this private information about the true quality to customers by the price. The more the vendor invests in the quality of the software, the higher will be the price. This relationship is reasonable for the monopoly vendor because an increase in the cost of the investment would cause the vendor to increase the price. We assume that the price and its quality are in a linear relationship, and that the price is represented by

$$p(s) = as + b, \ (0 \le s \le S) \tag{7}$$

where b is the price when the vendor does not invest in the unobservable qualities but invests only in the observable qualities, and a is a positive constant.

As in the previous model, we use a simple form of $K(s)$ represented by the function

$$K(s) = k - \beta s, \ (0 \le s \le \frac{k}{\beta}) \tag{8}$$

Then the vendor's profit will be

$$\begin{aligned} \pi(p,s) &= p(v-p) - K(s)(v-p) - s/N \\ &= (as+b)(v-as-b) - (k-\beta s)(v-as-b) - s/N \end{aligned} . \tag{9}$$

Proposition 4. When $p(s) = as + b$ and $K(s) = k - \beta s$, the optimal level of investment in the unobservable quality of an enterprise system, from the perspective of the software vendor, is

$$s^* = \frac{av - 2ab + \beta v - \beta b + ak - 1}{2a(a+\beta)} N \tag{10}$$

Proof. From the first-order conditions of Equation (9) with s, we can get the solution above. ■

5. Discussion

One of main findings in this study is that even if customers are uninformed about quality attributes, software vendors have incentive to invest for those quality attributes. This finding is an opposite result to Fishman and Simhon's (2000) findings, which argue that an investment equilibrium does not exist if buyers are uninformed about quality. One possible explanation of this result is that an enterprise system product consists of packaged software and services of customization and maintenance, and the weight of the services in enterprise system markets is much greater than in other product markets. For instance, electronic companies that sell appliances also provide customer services but much less costs are required in delivering the service than software vendors. Therefore, the unobservable quality that reduce costs of vendor's services of customization and maintenance affects software vendors' payoffs much more than companies in other industries, and causes the opposite result.

We identified optimal levels of the investment under two different pricing mechanisms. In competitive market, we assume that the price of enterprise systems is determined by customers' perceived quality, rather than the true quality that encompasses observable quality attributes and unobservable quality attributes, when customers make a decision on which system to purchase. With that assumption, we got the optimal level of the investment in Equation (6). According the Equation, as the amount of works for customization and maintenance k increases, the optimal level of investment in the unobservable quality increase. This finding is consistent with the vendors' practice that large-size software vendors, in general, invest more in the software development process along with unobservable quality attributes and they have more customers than small-size software vendors. Since more customers would mean that more amount of required tasks of customization and maintenance, we can conclude that, in the compeititve market, larger-size software vendors have more incentives to invest in the unobservable quality than small-size software vendors. In terms of the relationship between k and s^*, we got also the same result in the monopoly market where we assume that price is determined by the true quality rather than customers' perceived quality.

6. Conclusion

Many software vendors hesitate to increase their investment in the quality of a software package, particularly when the quality attributes are difficult for customers to evaluate prior to purchase. Software products that have identical observable features may be very different in their unobservable quality attributes. For example, a software program that should require at least one year to be developed when the development team follows a well-designed development process could be developed in a much shorter period if the development team does not include consideration of unobservable quality attributes such as modifiability, maintainability, and security. As a result of the vendor's noninvestment in the quality, customer organizations sometime have trouble after they purchase a vendor's enterprise system and adopt it. The main reason many software vendors do not invest in unobservable quality attributes is that they believe the investment may not increase or may decrease their profits. Our study shows that they may earn higher profits by investing in the unobservable quality in the game with customers.

One contribution of this study in academic areas is our work on an economic analysis of the software industry. Software is a representative digital product that, in some ways, shows different characteristics from traditional products. A number of previous studies have been conducted on the economic analysis of digital products, but we believe much more work is needed to understand the digital economy.

As mentioned in the Introduction section, the market size of enterprise systems is burgeoning larger. The deliverable of enterprise software vendors to customers is a combined form of packaged software product and service, and enterprise software companies have begun to sell their software as a service. With this trend, unobservable quality attributes that affect a vendor's costs in customization and maintenance services have been more emphasized and our study may have significant implications.

Further research is needed to analyze the results in Section 4 and find more significant implications of optimal investments. Then, more concrete guidelines could be provided to enterprise software companies and researchers in the stream. Our model has several limitations. First, we focus on quality and price as factors that determine the decision to invest. However, other factors, such as technical uncertainties, would also influence the vendor's decision. Second, we oversimplify the relationship between price and quality. In practice, not only quality, but also brand reputation, advertising, and customer relationships can affect a firm's pricing. In the future, a more generalized model that could encompass those factors will need to be developed. Third, we used different the cost functions of customization and maintenance, $K(s)$, in Section 4.1 and 4.2, so we was not able to compare the results.

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