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ERP Implementation Decisions under the Condition of (A)symmetric Information: an Agency Approach.

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Abstract: The optimization investment policy decision of an ERP implementation has been analyzed under symmetric and asymmetric information conditions. For both conditions, ERP implementation options' decision optimizing models have been developed. In these models, both clients and vendors try to pursue their own benefits. Based upon the principal-agent theory, the models show to what extent a principal (a client) needs to pay more to an agent (a vendor) in a context of asymmetric information. For the client, it is important to understand the extra costs to be able to adopt effective strategies to stimulate a vendor to perform an optimal implementation of an ERP system. The results of a simulation experiment regarding ERP implementation options illustrate and verify the theoretical findings and confirm the general notion that the less informed party is obliged to pay an information rent to the better informed party.

Keywords: ERP Implementation Problems, Asymmetric Information, Implementation Control Costs, Evaluation level, Principal-Agent Theory.

1. Introduction

There are large similarities between the way of handling ERP implementation options and financial options, as will be demonstrated in this paper. Hence, extending financial options' theory models can help us deal with ERP investment decisions [1]. The main idea is that several vendors are competing for the implementation rights. They can persuade the client to buy an ERP implementation in different ways. The vendor can, for example, lower his price. This action can be seen as the vendor buying an ERP implementation right option from the client. That is, during the auction, competing with other candidates, the vendor can buy the right to implement. Clients can invest in an ERP project, and grant permission to the vendor to implement. This allows both vendor and client to generate benefits from the induced investment. However, a vendor may choose not to buy the rights, but this will lead to the risk of being forced to stop his ERP activities since he is not able to implement the system he developed. Because the cost of having to stop the ERP activity is usually bigger than the cost of buying the clients' ERP implementation rights, a vendor commonly will choose to buy the implementation rights. Therefore, the client can make the best decision policy to stimulate the vendor to give the best quality implementation of an ERP system.

The dilemma of an ERP implementation can be looked at as a problem of information asymmetry as well. It is a bottleneck problem of disturbing industries' operations, especially of supply chain (SC) integration benefits [2]. A client, core enterprise or other member enterprise in the SC, adopts various measures to control the effect of an ERP implementation and to make sure he gets a sufficient part of the gains. But, when serious asymmetry exists between the client and the ERP vendor, an ERP implementation becomes very difficult.

As principals, clients may have different characteristics, resulting in various requirements. At the same time, the agent's (vendor) capabilities of implementing and maintaining client-specific ERP projects may be relatively low because he doesn't have all the information on the ERP's real implementation effects on the client's operation processes. On the other hand, a vendor may only care about

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his standard ERP implementation project, though this is possibly not suitable for the client's business. So, there is a possible trade-off between standardization and the capability to fulfill the specific needs of the clients (customization). Moreover, clients do not necessarily have a big inside into the impact of an ERP implementation since they might not be acquainted with the possibilities and limitations of an ERP system. Often, they are not familiar with technological problems when facing an ERP implementation, while the vendors are often not acquainted with the processes and operations of the enterprise or its supply chain. Thus there is asymmetric information between client and agent.

In addition, according to the asymmetry information theory, the vendors' private information on ERP implementations is regarded as external, and thus cannot be controlled directly by the client. It is just regarded as hidden information, causing information asymmetry. Hidden information is regarded as the first element constituting the asymmetric information theory. This is inevitably reflected in their implementation controlling actions. Given the hidden information, the vendors' contract choices may conflict with what clients expect since the vendor is not aware of the optimal solution for the client. Thus, sub-optimal or wrong choices can be made. This is referred to as adverse choosing, the second element of information asymmetry theory. Under the condition of hidden-action, vendors are tempted to maximize solely their own benefit and opt for a generic solution to serve as many clients as possible, neglecting the specific needs of the client. One party takes advantage of the other. This is referred to as moral risk, the third element of the information asymmetry theory.

In the paper, ERP implementation options' decision optimizing models are established. With clients as principal, vendors as agent, ERP implementation evaluation and deviation prevention principal-agent models are proposed. In these models, both clients and vendors try to pursue their own benefits. Based upon the principal-agent theory, the models show why a principal should stimulate an agent to pursue his benefits and to what extent a situation of asymmetric information is to his disadvantage.

2. ERP Implementation Options Decision's Principal Agent Model

As a principal, the client's ERP implementation benefit function, thus the principal's target function is:

$$Z_1 = P - C_A - (1 - P_A)P_E W - (1 - P_A)(1 - P_E)X \tag{1}$$

The gains are the vendor's offer minus the price for acquiring it, minus two parts, both indicating that the vendor's implementation result deviates from the negotiated standard. In one part the deviation is discovered by the vendor during the process (so the price can be adjusted). If the client notices it afterwards however, it must be deducted fully from his benefits.

Here, Z_1 is the client's controlled implementation benefit. P_E is a variable that represents the probability that a client discovers deviations from the agreed implementation's quality (described in the specifications of the contract between client and vendor) during its process.
$P_E \in [0, 1]$, and we call P_E the deviation control level.
P is the ERP implementation right option. It is a decision variable, and a function of the deviation prevention level P_E , $P = P(P_E)$.
C_A represents the client's cost, required to prevent bad implementation quality, and it is a function of P_A , $C_A = C_A(P_A)$.
P_A is the evaluation level of the implementation, given by the client. It indicates whether the implementation process corresponds to the agreed specifications. P_A is a function of $P_E, P_A = P_A(P_E)$. If P_E equals 0; then P_A equals 1 and W and X become irrelevant. In other words, if P_A is 1, the quality is perfect and there are no inner and outer losses. P_A reflects a client's subjective judgment and $P_A \in [0, 1]$.

W, X are constants that represent the vendor's inner and outer losses. Whereas the inner losses reflect deviations from the agreed quality (the specifications) during the implementation process (and thus are at the expense of the vendor); the outer losses refer to quality deviations, discovered after the implementation (and at the expense of the clients).

The actual quality control level P_A is smaller or equal to the clients' ideal solution. So the agreed implementation level (as specified in the contract) is equal or less than A. This is a constraint of the model, which is referred to as the clients' individual rational constraint (IR_C). According to literature [3], the IR_C should be reformulated as follows for calculation purposes:

$$Z_2 = \frac{1}{2}a(P_A - A)^2 \tag{2}$$

Here, a is a parameter that represents the vendors' greatest implementation evaluation ability, and $a > 0$. A vendors implementation controlling benefit function, that is, the agent's target function is

$$\begin{aligned} Z_3 = {} & P_A \Pi_G + (1 - P_A)P_E(U_E + W) \\ & + (1 - P_A)(1 - P_E)(\Pi_B + X) - P - C_E \end{aligned} \tag{3}$$

Here Z_3 is a vendor's implementation-controlling benefit.
Π_G is the vendor's benefit. It is the difference between the agreed value and the real value of his solution (so the difference between the amount in the contract and the amount actually paid by the customer).
Π_B is the vendor's benefit. It represents the clients cost for the discovery and correction of mistakes after the implementation of the system.
U_E is an agreed bonus (or premium) paid by clients in order to encourage vendors to discover and correct mistakes and avoid escalations later on.
C_E is the vendor implementation evaluation cost, it is a function of P_E , $C_E = C_E(P_E)$.

The function (Z_3) consists of two major parts. The first part ($P_A \mathit{\Pi}_G$) represents the perfect situation: the payment for a system that attains maximum quality. Another important part represents an imperfect situation,
$(1-P_A)(1-P_E)(\mathit{\Pi}_B+X)$ that is, the punishment for bad quality that is discovered by the client.

In the process of an ERP implementation decision, clients must consider their benefits. To calculate the client's benefits, we define the function Z and use equations (1), (2) and (3), thus considering three elements: the client 's gains of equation (1), the constraints of the client's equation (2) and the benefits of the vendor's equation (3).

$$Z = Z_1 - Z_2 + Z_3 \tag{4}$$

3. ERP Implementation Quality Evaluation and Options Payment Decisions

In order to minimize the risks of hidden information of the vendor and get the best possible implementation evaluation level P_A, especially when negotiating an ERP implementation contract, we compare two situations. The first is decision making under the assumption of symmetric information. The second situation deals with decision making under the assumption of asymmetric information (some information is hidden by the vendor).

3.1. ERP implementation Quality Evaluation and Options Payment Decisions under the Condition of Symmetric Information

Under condition of symmetric information between clients and vendors, clients can observe the vendors' implementation activities. Their ERP implementation decision problem is an optimization problem. The clients' targets are: (i) to choose an appropriate quality evaluation level P_A and implementation options payment P , and (ii) to maximize the client's benefit function, that is:

$$max\ Z = Z_{P_A,P}(P_A,P) \tag{5}$$

At the same time, under a system based on open competition, the vendor's benefits will tend towards zero, so that, $Z_3 = 0$, this means we can re-formulate equation (3) as follows

$$\begin{aligned} P &= P_A \mathit{\Pi}_G + (1-P_A)P_E(U_E+W) \\ &\quad +(1-P_A)(1-P_E)(\mathit{\Pi}_B+X) - C_E \end{aligned} \tag{6}$$

Substituting equation (6) into equation (4), gives the following result.

$$\begin{aligned} Z &= P - C_A - (1-P_A)P_E W - (1-P_A)(1-P_E)X \\ &\quad -\frac{1}{2}a(P_A-A)^2 \end{aligned}$$

$$0 = -C_A + P_E W + (1-P_E)X - a(P_A - A)$$

In order to maximize Z, we take the first and second derivative of the function.
Taking the first derivative of P_A , gives us:

$$C_A + a(P_A - A) = P_E W + (1-P_E)X$$

The second derivative of equation (4) is
$\frac{d^2 Z}{d{P_A}^2} = -C_A - a < 0.$
So under a condition of symmetric information, we find that:

$$P_A = \frac{P_E W + (1-P_E)X - C_A}{a} - A \tag{7}$$

The vendor's implementation quality level and the options payment decisions are:

$$P_A = P_A(P_E) \tag{8}$$

$$P = P(P_E) \tag{9}$$

3.2. ERP implementation Quality Evaluation and Options Payment Decisions under the Condition of Asymmetric Information

Now, consider the situation were vendors have ERP implementation knowledge (private information), and clients cannot obtain this information. As a result, the ERP implementation decision problem becomes an asymmetric information problem, which is a typical principal-agent problem [4]. Under these conditions, the client's target function can be described as shown in equation (10). The clients will choose a certain implementation evaluation level P_A, and an implementation option payment P to maximize the target function (4) under the condition of a client's expectation, that is:

$$max\ E(Z) = \int_{P_E^L}^{P_E^H} Z f(P_E) dP_E \tag{10}$$

Here, $E(Z)$ is the client's expected target benefit function under asymmetric information. The real client's deviation control level P_E is not known exactly but is situated between an upper and lower limit; $P \in [P_E^L, P_E^H]$. P denotes a probability density function $f(PE)$. And now, clients can estimate P_E . This estimation is called $\hat{P_E}$. $\hat{P_E}$ is a proxy for the real deviation control level, which is not yet known to the client. Clients will design a stimulus plan to obtain $\hat{P_E}$. This plan guides vendors to realize the deviation control level $\hat{P_E}$, targeted by the client [5]. According to the proclaimed axiom of the principal-agent theory [6], there is:

$$\begin{aligned} &\hat{P}_E = arg_{\hat{P}_E} max Z_3(\hat{P}_E) \\ &= arg_{\hat{P}_E} max[P_A(\hat{P}_E)\mathit{\Pi}_G + (1-P_A(\hat{P}_E))\hat{P}_E(U_E+W) \\ &+(1-P_A(\hat{P}_E))(1-P_B)(\mathit{\Pi}_B+X) - P(\hat{P}_E) - C_E] \end{aligned} \tag{11}$$

To maximize the target function (11) under the condition of a client's expectation, we take the first degree derivative of $\hat{P}_E$ and make it zero, that is:

$$\frac{dP}{d\hat{P}_E} = [\Pi_G - P_E(U_E + W) - (1 - P_E)(\Pi_B + X)]u = 0 \quad (12)$$

Where u is the first degree derivative of implementation quality evaluation level P_A to the deviation control level P_E 's estimated value $\hat{P}_E$, and it is a newly introduced controlling variable.

$$\frac{dP_A}{d\hat{P}_E} = u \quad (13)$$

Hence, the ERP implementation quality problem under asymmetric information can be regarded as an optimum control problem with following target functions: the benefit expectation equation (10) and the maximization functions (12) and (13). We assume that under the optimum control problem we get the best possible estimate for $\hat{P}_E$. Through proclaiming an axiom and stimulus strategy, the deviation control level comes close to the real value. Hence, we assume that $\hat{P}_E$ evolves towards P_E. So, in the next steps the real deviation control level P_E is deployed. Using the maximum axiom to seek a solution for this classic controlling problem, we construct the following Hamilton function, based upon equations (10), (11), (12):

$$H = Zf(P_B) + \lambda_P\,[\Pi_G - P_E(U_E + W) - (1 - P_E)(\Pi_B + X)]u + \lambda_{P_A} u \quad (14)$$

Here, λ_P , λ_{P_A} are parameters, introduced to solve the problem. To find the optimum solution, we need to maximize u, P and P_A . We take partial derivatives of the Hamilton function towards each of these variables:

$$\frac{\partial H}{\partial u} = \lambda_P[\Pi_G - P_E(U_E + W) - (1 - P_E)(\Pi_B + X)] + \lambda_{P_A} = 0 \quad (15)$$

$$\frac{\partial H}{\partial P} = -\frac{d\lambda_P}{dP_E} = (1 - b)f(P_E) \quad (16)$$

$$\frac{\partial H}{\partial P_A} = -\frac{d\lambda_P}{dP_E} = [-C_A + P_E W + (1 - P_E)X - a(P_A - A) + b[\Pi_G - P_E(U_E + W) - (1 - P_E)(\Pi_E + X)]]f(P_E) \quad (17)$$

Based upon equation (16), we can calculate λ_P :

$$\lambda_P = (b = 1)F(P_E) \quad (18)$$

Here, $F(P_E)$ is the probability distribution function of parameter P_E. We unite equations (15), (17) and (18), to get the client's quality evaluation level under asymmetric information (P_A^V):

$$P_A^V = P_A(a, b, P_E, f, F)$$

So, to get a high quality ERP implementation under asymmetric information; we maximize P_E and take its first derivative towards P_A^V , i.e.,

$$\frac{dP_A^V}{dP_E} = [\Pi_G - P_E(U_e + W) - (1 - P_E)(\Pi_B + X)]\frac{dP_A}{dP_E} \quad \Big|P_A = P_A^V \quad (19)$$

4. Comparing the Implementation Results under Symmetric and Asymmetric Information Conditions

Now that we have the maximum P_E under the assumption of symmetric and asymmetric information, we analyze and compare in this section the implementation evaluation level, P_A, in these two situations. P_A is dependent on P_E, it represents the evaluation of the ERP implementation quality and it is our principal decision variable. By comparing P_A in both situations and establishing whether and to what extent they differ, we can obtain the best policy to stimulate vendors to implement ERP systems optimally. In order to optimize P_A we need to consider the client's implementation evaluation cost function C_A as well as P_As first and second derivatives towards C_A, (which are all greater than 0). For the convenience of computation, we choose Yeom et al.'s cost function $C_A(P_A) = \frac{1}{2}K_A P_A^2$ [6]. Here, K_A is a general coefficient.

From equation (7) - the assumption of symmetric information - we get:

$$P_A = \frac{aA + P_E W + (1 - P_E)X}{K_A + a} \quad (20)$$

From equation (19) - the assumption of asymmetric information we get:

$$P_A^V = \frac{aA + P_E W + (1 - P_E)X}{K_A + a} + \frac{\Pi_G - P_E(U_E + W) - (1 - P_E)(\Pi_B + X)}{K_A + a} + \frac{(1 - b)F(\Pi_E - U_E - W + X)}{(K_A + a)f} \quad (21)$$

When we compare an implementation evaluation decision equation under symmetric information (20) with an implementation evaluation decision equation under asymmetric information (21) we find an increment, i.e.,

$$\Delta P_A = \frac{\Pi_G - P_E(U_E + W) - (1 - P_E)(\Pi_B + X)}{K_A + a} + \frac{(1 - b)F(\Pi_E - U_E - W + X)}{(K_A + a)f} \quad (22)$$

In order to further analyze the value of this increment we first consider the vendor's benefits and bonus: U_E, W and X. From section 2 we can define the following factors:

1. $(\Pi_G - U_E)$, the vendor's inner loss cost, meaning a vendor's losses when he discovers his own mistakes during the implementation;
2. and $(\Pi_G - \Pi_B)$ representing the vendor's outer loss cost, meaning the vendor's losses when the client discovers mistakes or deviations.

Now, suppose that the vendors' inner loss punishment is at least equal to the inner loss costs, $W \geq \Pi_G - U_E$, and suppose that the vendors' outer loss punishment is at least equal to the outer loss costs, $X \geq \Pi_G - \Pi_B$. Using N as a constant greater or equal to 1, we can establish:

$$\Pi_G - U_E = \frac{W}{N} \tag{23}$$

$$\Pi_G - \Pi_B = \frac{X}{N} \tag{24}$$

Substituting equations (23), (24) into equation (22), gives us the following result:

$$\Delta P_A = \frac{N-1}{(K_A+a)}[\frac{(1-b)F}{f}(X-W) - P_E W - (1-P_E)X] \tag{25}$$

From equation (25), we know: if $W > X$, $W - Z > 0$, and $\Delta P_A < 0$; then, $P_A^V < P_A$. That is, when vendors' inner loss punishment from the clients is greater than the outer loss punishment; the clients' implementation deviation control level under asymmetric information is less than that under symmetric information. If $N = 1$, and $\Delta P_A = 0$; then $P_A^V = P_A$; so, when vendors' inner-loss punishment from the clients is equal to the inner loss cost and his outer loss punishment is equal to the outer loss cost, clients' implementation deviation control level under asymmetric information is equal to the results under symmetric information.

If $W < X$, with X far greater then W, suppose, $X - W \approx X$, then:

$$\Delta P_A = \frac{N-1}{(K_A+a)N}\left[\frac{1-b)F}{f}(1-P_E)\right]X.$$

Presume that an implementation deviation prevention parameter $P_E \in [0.8; 0.9]$ has a uniform distribution $f(P_E)$, with $0.1 \leq 1 - P_E \leq 0.2$, and $0 \leq b \leq 1$, then $0 \leq 0.1(1-b) \leq 0.1$, and $0.1(1-b) - (1-P_E) \leq 0$, hence, $\Delta P_A = \frac{N-1}{N}[0.1(1-b) - (1-P_E)]X \leq 0$, so $P_A^V \leq P_A$; that is, when the vendors' inner loss punishment from the clients is less than the outer loss punishment, even when his outer loss punishment far exceeds the inner loss punishment, the clients' implementation evaluation level under asymmetric information will not be higher than the result under symmetric information. In sum, whether vendors' inner loss punishment from a client is greater or smaller than the outer loss punishment; the client's implementation quality level decisions under asymmetric information are all lower than under symmetric information. That is because, under asymmetric information, a client cannot observe the vendor's implementation activities, and he has to do his best to lower the implementation cost, that is, the implementation deviation prevention cost. When clients make implementation quality level decisions, the overall implementation control cost triggered includes implementation deviation control and implementation punishment costs. The mathematic equation is:

$$C = (1-P_A)P_E W + (1-P_A)(1-P_E)X + C_A \tag{26}$$

When $a = 0$, insert equation (20) under symmetric information and equation (21) under asymmetric information into equation (26). As a result we get:

$$C_{P_A^V} - C_{P_A} = \frac{(N-1)^2}{2K_A N^2}[\frac{(1-b)F}{f}(X-W) - P_E W - (1-P_E)X]^2 \tag{27}$$

Here, $C_{P_A^V}$ is the client's implementation control cost under asymmetric information. C_{P_A} is the client's implementation control cost under symmetric information. Equation (27) shows, the clients' implementation controlling cost under asymmetric information is higher or equal to the result under symmetric information. IF $N = 1$, then $C_{P_A^V} - C_{P_A} = 0$.

Consequently, when the vendor's inner loss punishment is equal to the inner loss cost and his outer loss punishment is equal to the outer loss cost, the clients' implementation control cost under asymmetric information is higher than the result under symmetric information. This shows that, under asymmetric information, a principal must pay the implementation control cost and should strive for an implementation agreement in which the condition of symmetric information is met as much as possible.

5. Simulation Calculations

In this section, an implementation level decision problem of a client under asymmetric information with varying deviation control levels is presented.

Suppose that the client's achieved benefit is $\Pi_G = 5000$ EUR if the vendor implements the system as agreed in the contract between vendor and client. Further presume that the client evaluated the implementation, and the vendor timely adopted implementation control measures. Under the assumption that the client has spent 1000 EUR evaluating the implementation and detecting the deviation from the agreed quality level, the client's benefit is now $U_E = 4000$ EUR.

Next, consider that the client's achieved benefit would be $\Pi_B = 3000$ EUR (instead of 5000 EUR) if the vendor has the possibility to deviate from the agreed implementation quality level. The client punishes the vendor's inner loss $W = 2000$ EUR; the outer loss punishment of the vendor is $X = 4000$ EUR. The client's highest implementation deviation prevention level is $A = 0.98$. In addition, $a = 0.1$, $b = 0.1$. Consider:

- The vendor's implementation evaluation cost function $C_E(P_E)$ to the implementation deviation prevention level

P_E 's first and second degree derivatives are both greater than 0;
- The client's implementation prevention cost function $C_A(P_A)$ to the implementation evaluation level P_A's first and second degree derivatives are both greater than 0;
- And for the convenience of dealing, choose the vendor's evaluation cost function $C_E(P_E) = \frac{1}{2}K_E P_E^2$, and the client's implementation deviation prevention cost function $C_A(P_A) = \frac{1}{2}K_A P_A^2$, $K_A = K_E = 4000$.

Suppose a vendor's implementation deviation prevention coefficient, $P_E \in [0.8; 0.9]$, and suppose it has a uniform distribution $f(PE) = 10$. P_E has the following value:
$P_E = P_{B_0} + n_E = 0.8 + 0.005n, n = 1, 2, ..., 20.$

Given these calculations and assumptions, the decision results for the client are given in figure 5.1 and figure 5.2. In the figures, a full line represents decision results in the case of symmetric information, whereas a dashed line represents the results under a condition of asymmetric information. Figure 5.1 shows that the implementation quality level, P_A , under asymmetric information is lower than the quality level under symmetric information, for varying levels of P_E . Figure 5.2 denotes that the client's implementation control cost under asymmetric information is higher than that under symmetric information, for different levels of P_E . It is thus clear that the condition of asymmetric information benefits the vendor and makes the client pay for the price of the implementation controlling cost.

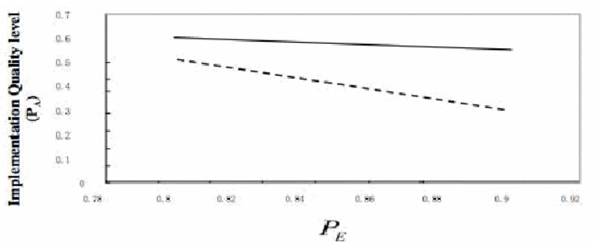

Figure 1 Implementation quality level under asymmetric information conditions.

6. Conclusions

In this paper, the option theory and the theory of asymmetric information were used to examine ERP implementation decisions under symmetrical and asymmetrical information conditions. In particular, ERP implementation options' decision optimizing models were established and ERP implementation deviation prevention and evaluation principal-agent models were created. In these models, both clients (principals) and vendors (agents) try to maximize their own benefits.

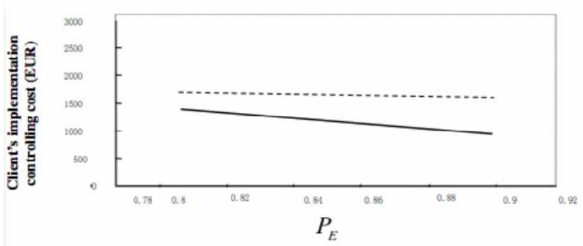

Figure 2 Clients' quality level under asymmetric information conditions.

Under the condition of asymmetric information, vendors hide their implementation information, which makes it a typical principal-agent problem. In this setting, the client's target function is the subject of an optimum control problem and the clients' targets are: (i) to choose an appropriate quality evaluation level and implementation option's payment, and (ii) to maximize the benefit function. The optimized results show the feasibility of using theories of options and asymmetric information to understand and solve ERP implementation option decisions.

The application of a simulation illustrates that the client's required implementation quality level under asymmetric information is clearly lower than that under symmetric information. In addition, the client's implementation control cost under asymmetric information is higher than that under symmetric information.

As a result, it is important to research the nature of hidden information and conduct further research in the development of effective clients' strategies to optimize the level of symmetric information to avoid the risk of hidden ERP implementation costs.

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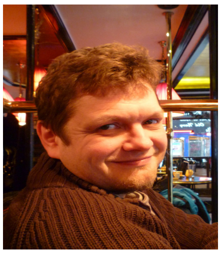

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