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Application of Bayesian Game Model in Government Departments' Decision-Making of E-Government Information Sharing

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Abstract

Government departments can effectively utilize information resources and improve public service quality and administrative capacity when involve in e-Government information sharing, but there are additional costs of the information sharing. Employing a Bayesian game model with white noise, the decision-making of government departments to involve in e-Government information sharing under the condition of e-Government coordination and incomplete information is analyzed. A unique equilibrium obtained through this model describes that when all government departments make decisions under rational principles (instead of random principles), part of them decide to involve in e-Government information sharing, while the others decide not. This equilibrium is more close to the reality. According to the parametric analysis, the proportion of government departments in e-Government information sharing is affected by the division level of government departments functions, the expected benefits of information sharing, the degree of interdependence of government departments and the differences of government departments. The good results are got form the instance.

Keywords: *Bayesian game model, coordination, e-Government, information sharing, incomplete information*

1. Introduction

Government departments can effectively utilize information resources and improve public service quality and administrative capacity when involve in e-Government information sharing, which will further enhance the government departments' efficiency and performance [1-4]. However, e-Government information sharing needs inter organizational collaboration. And technical, organizational, legal and politic barriers affect the departments' initiatives to involve in e-Government information sharing [4-8].

Relevant researches have been done in some current literatures. Dawes suggested that the expected benefits and risks of information sharing gave government policies some guidance [9]. Bekkers proposed that building flexible infrastructure was conducive to information exchanges [10]. McDougall et al. observed that good partnerships among government departments could encourage them to involve in information sharing [11]. Yang, *et al.*, analyzed the boundaries of information sharing and integration [12]. The above researches focused on the influencing factors, methods and incentive mechanism of information sharing in government departments and few researches have analyzed the decision-making of government departments on e-Government information sharing.

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In summary, this paper compensates for the deficiencies of previous literatures by employing a Bayesian game model with white noise, analyzes the decision-making of government departments to involve in e-Government information sharing in detail. Distinguished from similar researches, this paper analyzes the effects of e-Government coordination and incomplete information on the decision-making of government departments. The unique equilibrium and the results of parametric analysis have a certain reference value to micro policy of government departments and macro management of government information resources.

2. Background

Government departments control most social information resources, and informationization has been the focus of every government. With the rapid development of information and communication technologies, e-Government has become the main field of information construction. Establishing information resources management platform is conductive to all-round development of e-Government, which help various levels of government and departments reasonably exchange and utilize information resources of e-Government. However, establishing information resources management platform needs government departments to make efforts and coordinate to involve in e-Government information sharing, which forms e-Government coordination [13, 14]. E-Government coordination causes inter organizational interdependence, which makes efficiency and performance of e-Government information sharing depend on the proportion of government departments in e-Government information sharing. Government departments with increasing proportion would capture more information resources from information resources management platform, as well as higher efficiency and performance, and vice versa. Therefore, e-Government coordination leads to complex decision-making of government departments. They should consider not only the prospect of e-Government information sharing, but also other government departments' decisions.

Government behaviors often base on government departments participation, and every department maintains its own information system. Not-matched data structures and inconsistent standards of those information systems result in the poor collaborative capacity among government departments [4, 5]. Different targets, values, resources as well as privacy and safety concerns among departments, lead to different expectations on e-Government information sharing [4-6, 15].

Besides, government departments as different stakeholders, consider its optimum target when make decision to involve in e-Government information sharing. And one department's decision will influence other departments' decision-making. Hence, it is impossible to completely know the true situations of other government departments, which means the decisions to involve in e-Government information sharing are made under incomplete information condition. It would cause decision-making risks that enhanced efficiency and performance would not obtained through e-Government information sharing. Therefore, this paper shows theoretical and practical implications on the decision-making of government departments to involve in e-Government information sharing, by employing a Bayesian game model with white noise to analyze the effects of e-Government coordination and incomplete information [16].

3. Complete Information Static Game Model

3.1. The Game with Two Government Departments

Assuming there are two different government departments in the government information resources management platform, which assure the existence of e-Government coordination and complete information. Government departments have two choices: involving in e-Government information sharing, or not. We get a basic model similar to "gender war" game, referring to Figure 1.

		Department A: Involving	Department A: Not involving
Department B	Involving	r, r	$r-f, 0$
	Not involving	$0, r-f$	$0, 0$

Figure 1. The Game with Two Government Departments

As shown in Figure 1, r as the benefit of single department with all government departments in e-Government information sharing (for convenient to analyze the model, this paper describes the efficiency and performance from e-Government information sharing as the benefits of government departments), $f(l)$ as the benefits interdependence of government departments, derived from e-Government coordination. If either of them do not involve in, benefit of the government department which involves in decrease comparing with r. Because there are only two government departments in this model, the one which involves in will get a larger loss, to get $r - f < 0$. The government department which does not involve in will have neither additional costs of building infrastructure nor any benefits, to get 0.

There are two pure-strategy Nash equilibriums: (involving, involving) and (not involving, not involving). There exists at least one mixed-strategy Nash equilibrium which two government departments respectively choose to involve in e-Government information sharing or not randomly with a certain probability.

3.2. The Game with n Government Departments

We extend the situation of two government departments to n government departments in the government information resources management platform, government departments have higher division of functions, as n is bigger, which assure the existence of e-Government coordination and complete information. Government departments still have two choices: involving in e-Government information sharing, or not.

Let r still as the benefit of single department with all government departments in e-Government information sharing. Here, $f(l)$ as the benefits interdependence of government departments with e-Government coordination. If there are n_1 $(n_1 \le n)$ government departments not involving in e-Government information sharing, the benefits of departments

in e-Government information sharing will decrease comparing with r . Here, $f(l)$ is a strictly increasing function, $l = \frac{n_1}{n}$, $0 \le f(l) \le F$, and F is a positive constant, and $f\left(\frac{n-1}{n}\right) > r > 0$, $f(0) = 0$. That means the benefit loss of government departments involving in e-Government information sharing, brought by those not, is limited. Define $r(l)$ as the benefit function of single government department involving in e-Government information sharing, so the equation (1) is

$$r(l) = r - f(l) \tag{1}$$

The government department i faces the decision-making whether involve in e-Government information sharing or not.

Suppose other government departments involve in e-Government information sharing. When government department i does not involve in information sharing, it will not get any information resource from the information resources management platform. The department i will have neither additional cost nor any benefits from e-Government information sharing, to get 0. When the department i also involves in, it will get r , the benefit of single government department from e-Government information sharing.

Setting other government departments do not involve in e-Government information sharing, the department i gets 0 when it does not involve in e-Government information sharing. When the department i involves in e-Government information sharing, it will not get any information resource, but extra cost, so it gets $r - f\left(\frac{n-1}{n}\right) < 0$. That is a failure of the department i .

Drawn from the conclusion, if other government departments involve in e-Government information sharing, the optimal choice of government department i is to involve too. And if other government departments do not involve, the optimal choice of department i is also not to.

Now, there are two pure-strategy Nash equilibriums: (involving, involving…, involving) and (not involving, not involving…, not involving). That is all the government departments simultaneously involve in e-Government information sharing or simultaneously not.

Moreover, according to the Game Theory, there exists at least one mixed–strategy Nash equilibrium: government departments choose to involve in e-Government information sharing or not randomly with a certain probability.

The above model with two pure-strategies Nash equilibriums describing government departments' behaviors only can explains two extreme cases. Namely, all government departments make the same decision. However, the more common situation in reality is part of the government departments involving in e-Government information sharing, while the others not. Moreover, the government departments' decision-making is the only option under the rational principle (not at random). Mixed-strategy Nash equilibrium is not able to explain this intermediate state.

4. The Static Game with Incomplete Information and the Equilibrium

4.1. Introduction of the Incomplete Information

In reality, the information is incomplete when the government department i makes the decision of involving in e-Government information sharing. First the department i can't accurately estimate the proportion of government departments in e-Government information sharing, so it can't determine the benefit r . Then, the department i can't accurately judge the decision-making of other government departments. Even if another government department j declares to involve in e-Government information sharing, its infrastructure construction may not succeed at all. When department j involves in e-Government information sharing, its activity may not conform to the law or policy, or its information sharing system may be incompatible with other systems. These will lead to failure to carry out e-Government information sharing. Therefore, introducing the incomplete information into the model will more conform to the common situation of the departments' rational decision-making.

Suppose government departments do not know the accurate benefit r , except for a random variable r , and the distribution of a priori probability on r is $N\left(\overline{r}, \frac{1}{\alpha}\right)$, in which $\overline{r}$ is the government departments' expected benefits when involving in e-Government information sharing and $\frac{1}{\alpha}$ describes the differences of government departments. Each government will predict a benefit r_i , before making decisions. Due to the differences of departments' targets, values, resources and noise in information systems construction process, different department will predict different r_i . There is an error ε between r_i and the real r (prediction errors of the government department i and j are respectively ε_i and ε_j). Then the prediction of benefit r_i of department i is the equation (2)

$$r_i = r + \varepsilon_i \tag{2}$$

Here, $\varepsilon \sim N\left(0, \frac{1}{\beta}\right)$ and $\frac{1}{\beta}$ is the government departments' information noise. Setting the information noises of different departments are independent, which means ε_i is independent of ε_j and r_i is independent of ε_i . All distributions are common knowledge and r_i are the private information of department i .

According to the equation (1), when the proportion of government departments not involving in e-Government information sharing is l , the government department i 's expectation function of benefits from e-Government information sharing is the equation (3)

$$r_i(l) = r_i - f(l) \tag{3}$$

Because of incomplete information, the department i can't know the decision-making of other government departments which brings uncertain proportion l . The department i has to estimate l according to its own prediction of r_i . Setting the estimation value of l is l_i , when the department i predicts r_i , and the ordinary form of equation (3) is the equation (4)

$$r_i(l_i)\big|_{r_i} = r_i - f(l_i)\big|_{r_i} \tag{4}$$

In which, "$\big|_{r_i}$" represents the case of the department i predicting r_i.

4.2. The Bayesian Game Model

Assuming that risks of government departments are neutral, the government departments should make decision basing on the mathematical expectation of benefits predicted by them. According to equation (4), the equation (5) is got

$$E[r_i(l_i)]\big|_{r_i} = E(r_i)\big|_{r_i} - E[f(l_i)]\big|_{r_i} \tag{5}$$

According to the statistics, when the government department i predicts r_i, the distribution of a posterior probability of the department i on r is $N(\rho_i, \mathrm{var}\, r)$ [16], in which the equation (6) is got

$$\rho_i = \frac{\alpha \bar{r} + \beta r_i}{\alpha + \beta}, \mathrm{var}\, r = \frac{1}{\alpha + \beta} \tag{6}$$

Thus, the department i can infer ρ_i if r_i is predicted. That is predicting r_i means knowing ρ_i. Therefore, a Bayesian game model can be got.

The department i knows ρ_i without knowing $\rho_j (i \neq j)$ and ρ_i is the type of the department i. The department i makes decision basing on its own type and the estimation of the others' types. The decision-making criteria are:

$E[r_i(l_i)] > 0$, the government department i involves in e-Government information sharing;

$E[r_i(l_i)] < 0$, the government department i does not involve in e-Government information sharing;

$E[r_i(l_i)] = 0$, no differences for the government department i to involve in e-Government information sharing or not.

4.3. The Equilibrium

According to the former researches [16], when $f(l)$ is a linear function and the information noise $\frac{1}{\beta}$ is sufficiently small, Bayesian Nash equilibrium ρ^* uniquely exists in the model, which makes the government departments of type $\rho_i \leq \rho^*$ not involve in e-Government information sharing, while others of type $\rho_i > \rho^*$ involve in e-Government information sharing.

For the value of ρ^*, set $f(l) = bl$ (b is a constant and $b > 0$), in which b represents the degree of interdependence of government departments. Then the equation (7) is got

$$\rho^* = \frac{b(n-1)}{n} prob(\rho_i < \rho^*) \tag{7}$$

ρ^* is the only solution to the equation (8) [16]

$$\rho^* - \frac{b(n-1)}{n}\Phi\left(\sqrt{\gamma}\left(\rho^* - \bar{r}\right)\right) = 0 \tag{8}$$

In which, $\gamma = \frac{\alpha^2(\alpha+\beta)}{\beta(\alpha+2\beta)}$, and Φ is a standard normal distribution function.

Since ρ^* is unique, the model has a unique Bayesian Nash equilibrium, which explains the real common situation. When all the government departments make decisions under rational principles, some of them decide to involve in e-Government information sharing, while the others decide not to.

4.4. Parametric Analysis

According to equation (7), the proportion of government departments involving in e-Government information sharing is the equation (9)

$$p(\mathrm{A}) = prob\left(\rho_i > \rho^*\right) = 1 - \frac{n}{b(n-1)}\rho^* \tag{9}$$

It's easy to know that the value of $p(\mathrm{A})$ varies with the changes of ρ^*. The bigger ρ^* is, the smaller $p(\mathrm{A})$ will be.

Partial derivative shows that when the information noise $\frac{1}{\beta}$ is sufficiently small, the parameters n, $\bar{r}$, b and α have effects on ρ^* [16], which means the proportion of government departments in e-Government information sharing varies with the parameters. Then the conclusions are here:

Conclusion 1: according to the equation (9), with n increasing, ρ^* will increase, and $p(\mathrm{A})$ will decrease. This means the higher the division level of government departments functions is, the smaller the proportion of government departments in e-Government information sharing will be. The explanation is the coordination becomes difficult because of the high division level of government departments functions and government departments can hardly reach unanimity on whether involving in e-Government information sharing or not.

Conclusion 2: Since $\frac{\partial\rho^*}{\partial\bar{r}} < 0$, with $\bar{r}$ increasing, ρ^* will decrease, and $p(\mathrm{A})$ will increase. That is the larger the government departments' expected benefits of e-Government information sharing is, the more initiative the government departments will show in e-Government information sharing, which will lead to a larger proportion of.

Conclusion 3: Since $\frac{\partial\rho^*}{\partial b} > 0$, with b increasing, ρ^* will increase, and $p(\mathrm{A})$ will decrease. This means the higher the degree of interdependence of government departments is, the smaller the proportion of government departments in e-Government information sharing will be. This indicates all government departments are very cautious about involving in e-Government information sharing. When there is high degree of interdependence, the

departments worry that if they involve in e-Government information sharing, they will lose since other departments do not involve in e-Government information sharing.

Conclusion 4: Since $\frac{\partial \rho^*}{\partial \alpha} < 0$, with $\frac{1}{\alpha}$ increasing, ρ^* will increase, and $p(\mathrm{A})$ will decrease. It means the bigger the differences of government departments are, the more difficult the construction of information resources management platform will be, and the higher risk the government departments will face, which lead to a smaller proportion of government departments in e-Government information sharing.

5. Instance

There is an instance explaining the model directly. Assume there are 10 government departments ($n = 10$), and the distribution of a priori probability on r is $N(5,1)$ (that is $\bar{r} = 5, \alpha = 1$), and prediction error of government departments $\varepsilon \sim N\left(0, \frac{1}{15}\right)$ (that is $\beta = 15$). Meanwhile, the benefit loss $f(l) = 10l$ (that is $b = 10$) and government department i and j predict $r_i = 3.8, r_j = 3.4$ respectively.

According to equation (7), (8), ρ^* can be got ($\rho^* = 3.6$) and according to equation (6), we get $\rho_i = 3.875$, $\rho_j = 3.5$, $\rho_j < \rho^* < \rho_i$. It indicates the department i will involve in e-Government information sharing, while the department j will not.

If the external factors (government policy, *etc.*,) is advantageous to the e-Government information sharing, the government departments' expected benefits $\bar{r}$ will increase to 5.2, which results in $\rho^* = 3.2$, $\rho_i = 3.888$, $\rho_j = 3.513$, $\rho^* < \rho_j < \rho_i$. It means the department i and j will involve in information sharing. If the government departments are restricted by the internal factors (technology, cost, *etc.*,) the expected benefit $\bar{r}$ will decrease to 4.75, which brings $\rho^* = 4$, $\rho_i = 3.859$, $\rho_j = 3.484$, $\rho_j < \rho_i < \rho^*$. That indicates the department i and j will not involve in information sharing. The effects of other parameters are similar to the analysis of the above instance.

According to the above instance, government departments can infer the expected benefits to make rational decisions to involve in e-Government information sharing basing on the changes of external and internal factors. And the information resources management departments can formulate effective policies and laws to indirectly prompt government departments to involve in e-Government information sharing.

6. Conclusions

Employing a Bayesian game model with white noise, this paper analyzes the decision-making of government departments to involve in e-Government information sharing under the condition of e-Government coordination and incomplete information. The real common situation can be explained by the unique equilibrium in the model. Some suggestions are proposed in the following.

(1)In order to increase the proportion of government departments in e-Government information sharing, a stable external environment should be offered by the government through formulating rational policies and laws as well as some encouragement and

punishment measures. On one side, government can provide certain technical and economic supports to compensate the government departments for their additional costs of e-Government information sharing, and the departments' doubt about involving in information sharing will be dispelled. On the other side, government can give some punishment to those government departments not involving in e-Government information sharing. Moreover, coordinating government departments more easily, the number of government departments can be simplified and the division level of government departments' functions can be decreased.

(2)In order to reduce the risks the government department's face, the external and internal environment factors should be analyzed in detail by the departments, and their abilities should be enhanced to protect information from disclosure. Besides, the managers of government departments should encourage and support their departments to involve in e-Government information sharing.

The limitation of this paper is that the model only focuses on the effect of the proportion of government departments in e-Government information sharing on the decision-making of government departments. Further research on the efficiency and accuracy of information is needed. In addition, the theoretical conclusions in this paper also need further be tested by empirical researches.

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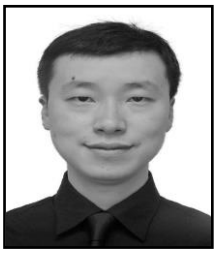

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