Game Modeling and Strategic Behavior Analysis of Stakeholders in Public Goods Provision

--Evidence from Water Resources Management

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Abastract: The utility of public goods vary with the behaviors of stakeholders (players), and it is appropriate to study effective supply and management of Public Goods with game modeling and analysis. In the first section of this paper, the definition of integrated water resources management(IWRM), the importance of stakeholder participation in water management and some models as well as methods that have been applied for this issue are illustrated. Following this, the framework of analysis is elaborated. Within this section, the scenario and aims are shown, and it is claimed that game theory is the main approach, which includes both cooperative games and non-cooperative games. To achieve the aims of the public project, five approaches from game theory are able to cover the entire process of the project, and the fourth approach on interest compensation mechanism is the highlight of the research. After this, the interest compensation mechanism is demonstrated in the model section, and is proved to be an incentive compatible mechanism that makes each stakeholder choose to behave in accordance with the interest of the entire project. The Clarke-Groves mechanism is applied in establishing the model, and the utility change by the comparison among stakeholders (defined as the comparison effect) is involved. In the application section, a water project is analyzed in consideration of various stakeholders, and other possible applications are also indicated.

Key Words: Integrated water resources management (IWRM), game theory, interest compensation mechanism, The Clarke-Groves mechanism

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1. Introduction

It is an arising and active area to study public goods provision with game modeling and experimental game methods in game theory and public management. Water management that depends on interacting or strategic behavior of stakeholders (players) is a type of public goods as well, and it is more appropriate to analyze them with game modeling and analysis. Issues related to water resources have attracted increasingly more attention as the problems of water shortage and water pollution hinder economic growth and affect social progress. As a result, voices calling for integrated water resources management (IWRM) have been heard in different places all over the world. In the process of integrated water resources management, stakeholder involvement, public participation and multi-stakeholder analysis are usually emphasized in many management domains.

As for the content of integrated water resources management, it is defined in different ways after its emergence. A most commonly cited definition was given by Global Water Partnership (2000), which can often be read in literature related to IWRM. It was defined that "IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." This definition was well elaborated by Biswas (2004), and another relatively comprehensive definition was cited in Jaspers's article (2003) (cf. Van Hofwegen & Jaspers, 1999). Being a widely used tool for multi-stakeholder analysis, the concept of multi-stakeholder platform is often seen in literature, and Warner (2005) unpacked and analyzed that. Meanwhile, Warner supposed that multi-stakeholder processes, multi-stakeholder partnerships, multi-stakeholder dialogues, multi-stakeholder fora and multi-stakeholder roundtables can also be used as multi-stakeholder platforms if the focus is wide enough.

1.1 The Importance of Stakeholder Participation

Stakeholder analysis is widely used in many fields, and stakeholder participation can help to build a better relationship among stakeholders as well as a more harmonious relationship between human beings and nature. Ostrom (1990) considered the roles of different people in natural resources in solving the problem of "the tragedy of the commons" (Hardin, 1968). Later, Ostrom (1998) demonstrated that strong temptations of short-run self-interest can be overcome with the help of reciprocity, reputation, and trust. With regard to water, Moss, Downing and Rouchier (2000) argued that inevitably where water is concerned, concerns of stakeholders reflect or engender social conflict. Therefore, solving conflicts in water resources management has always been a heated topic for research.

For a long time, technological fixes have been an efficient way in solving urgent environmental problems, but dissatisfaction and much expenditure requires public opinion which is also aroused by environmental awareness (Pahl-Wostl, 2002a). In Jaspers's article (2003), it was stated that stakeholder participation has become a crucial issue and water resources planning without stakeholder participation is highly ineffective. In addition, Mostert et al. (2007) found that participatory processes can lead to changes in river-basin management and benefit all stakeholders as well as the environment. These processes increased the understanding of key issues in management, helped to build trust and improve relations, established and developed new organizations. Hemmati (2002) concluded the benefits of Multi-Stakeholder Processes (the similar concept to multi-stakeholder platforms, MSPs): (1) The quality of opinion-forming and decision-making is improved. (2) Credibility and moral authority can be gained if done in an equitable, transparent and democratic way. (3) People's commitment to the outcomes and implementation can be enhanced. (4) Mutual respect and tolerance in society are increased, and conflict on contentious issues can be solved more easily.

1.2 Models and Methods Applied in Literature

After many became aware of the significance of stakeholder participation, various models and methods were applied in stakeholder participation and multi-stakeholder analysis. As early as 1985, Henderson and Schilling used decision support systems (DSS) in the public sector for a community mental health system as an experience, and this DSS can also support other decision process in the public sector. The DSS encompasses a multiple objective allocation model as well as a multiple party decision process. Moss, Downing and Rouchier (2000) applied simulation modeling for water demand policy and response in consideration of stakeholder participation. In addition, by using The Integrated Systems for Knowledge Management (ISKM) as framework, collaborative learning and information sharing process was conducted (Allen et al., 2001).

In the research conducted by Borsuk et al. (2001), many means were applied, such as literature searches, phone interviews, personal interviews, public meetings, written surveys or questionnaires. They relied on a probabilistic model which is called probability network, and this depicts probabilistic relationships among uncertain variables. Hamalainen et al. (2001) used modeling approaches to group decision support based on Multiple Criteria Decision Making (MCDM), and value tree analysis, Pareto-optimality and consensus seeking were applied and role playing experiments were conducted to evaluate and improve the models. Besides, Turcotte and Pasquero (2001) introduced the method of Multi-stakeholder Collaborative Roundtable (MCR),

and considered the outcomes in three aspects: consensus, learning and problem solving capacities.

Pahl-Wostl (2002b) mentioned that the focus group, an important and novel method in integrated environmental assessment, is widely used in public opinion research and in marketing. Pahl-Wostl also introduced agent-based models (ABMs). Wang et al. (2003) utilized a cooperative game approach in water allocation, and achieved efficient use of water through water transfers by reallocation of water. In the case of South Africa, Simpungwe (2006) examined the central issues of Catchment Management Forums (CMFs) which are one of the new institutional forms being referred to as MSPs. Desktop research (secondary data collection), informal survey, interviews, participant observation, stakeholder analysis and workshops were used as major methods and techniques.

These methods provide remarkable insights for the application of stakeholder participation in various situations, especially for water resources management. Some means can be adopted in the research, but at the same time, application highly relies on the specific scenario, which requires modification and adaptation in utilizing them and innovation for further development.

2. The Framework of Analysis

The main scenario in this paper is a water project, for example, a water diversion project or a desalination project, which is one major domain in water resources management, and is especially important for China in many areas where water shortage has become a severe problem. The entire project discussed here can be divided into three parts: preparation for the project, construction of the project and operation, maintenance and renovation after completion.

In the water project, aims in two aspects are to be fulfilled. One is people's harmonious relationship with the environment, a basic principle in making the project more sustainable in the future. After longtime development, it is commonly accepted that nature is an indispensable foundation for human development, and any kind of large project should consider the impact imposed on the environment. If the project can not get along well with the surroundings, it can not be sustainable in the long run. Another is the economic and social aspect. Public participation is increasingly important in decision making, and the simple but difficult target is to let all stakeholders join the decision process and finally gain from the project (at least not worse off). One reason for this is that more participants may generate more ideas and potentially enriches process substance (Edelenbos and Klijn, 2006). In addition, willingness as well as acceptance of the stakeholders heavily influences the construction and maintenance of the project from the micro perspective, and the social

welfare and social stability in a much wider range. In a more comprehensive way, Global Water Partnership (2003) illustrated principles for effective water governance which require approaches to be open and transparent, inclusive and communicative, coherent and integrative, equitable and ethical; performance and operation should be accountable, efficient, responsive and sustainable. These should be well taken into account in water projects. In this paper, the emphasis is mainly put on the economic aspect.

The analysis of stakeholders in water resources management for this paper highly emphasizes on the strategic behaviors of stakeholders. Although commonly used methods in MSPs are necessary to be adopted, such as written surveys or questionnaires, interviews, collaborative learning, public meetings, formal or informal visits and information sharing, the most important technique in the analysis is the use of both cooperative games and non-cooperative games.

First of all, water resources management involves many stakeholders from different sectors, which makes it more difficult to find equilibrium for multi-stakeholder analysis in considering comprehensively the interests of various stakeholders. Just within the first level of stakeholders in this specific scenario, there are stakeholders from the government, residents, industries and other possible stakeholders, not to mention the secondary level or even the tertiary level. In this sense, it is clearer and more convenient to use game theory approaches to analyze strategic behaviors of stakeholders. Besides, cooperative games and non-cooperative games are both applied. The overall project is a complicated and long-lasting task, the analysis of which is diversified for various aspects during the process. Hence, both cooperative games and non-cooperative games are to be considered. In addition, water resources management often lasts for a long time, and situations often change after more information is disclosed and participants get to know each other better. Therefore, multi-stage analysis is needed so as to reflect the dynamic changes as time goes on. On the whole, the framework of the analysis is a multi-stage, multi-stakeholder, multi-domain, multi-factor and multi-target game analysis process. Within the entire process, five major approaches are of great significance, thus needing explanation. Before explaining the five major approaches in detail, some general definitions are to be illustrated:

(1) The set of players is illustrated by N, and $N=\{i:i=1,2,\cdots,n\}$, where individual $i\in N$. This shows that there are n stakeholders in the model. They represent different stakeholders from the government sector, residents, different industries and other possible entities. It is to be noted that government agencies are involved as stakeholders in this model to represent the administrative factors.

Although some of them still help to coordinate various stakeholders in this project, their own benefits and losses are taken into account in the model.

(2) For each stakeholder i, the set of strategic behaviors is S_i, and one strategic behavior is $s_i \in S_i$. The entire space of strategic behaviors is $S = S_1 \times S_2 \times \cdots \times S_n$.

(3) The space of information is $\Theta = \{\theta_1, \theta_2, \cdots, \theta_n\}$. θ_i is specifically known by individual i, for $i = 1, 2, \cdots, n$, and can not be directly revealed to other stakeholders.

In the following, five major stages within the strategic analysis are given, and a brief illustration of the five stages as well as mechanisms and possible models that may be applied can be found in Table 1.

Table 1. Five Stages of Stakeholder Analysis.

Stage	Mechanism applied	Possible model
Disclosure of information	Mechanism for telling the truth	The revelation principle
Negotiation mechanism	Negotiation mechanism	Nash negotiation model
Incentive mechanism and regulatory mechanism	Incentive/penalty/regulatory mechanism	Principal-Agent model, incentive mechanism design, optimal contract
Interest compensation mechanism	Clarke-Groves mechanism	Free-riding model in public goods, interest compensation
Trust and sustainable development	Sustainable and cooperation mechanism	Trust games, dynamic/repeated games, evolutionary games, reputation model

1. Disclosure of information. Without knowing the actual information of the stakeholders, it is hard to determine how much each stakeholder should pay for the project. Hence, understanding how to reveal the private information of each stakeholder is necessary. In this process, the objective is to make each stakeholder tell the truth and reveal his or her real revenue and loss. By doing so, it becomes possible to let stakeholders bear their costs in a relatively fair way and finally gain benefits from the operation of the project. This belongs to non-cooperative games, and can be realized mainly by the revelation principle.

2. Negotiation mechanism. During the preparation period of the project, general consensus should be made before construction. In the construction period and

maintenance stage, when problems arise, negotiation mechanism can also be effective. In practice, meetings and workshops can be held to get stakeholders together and discuss problems that appear in the project. During this process, information and ideas are exchanged through communication, and people will adjust their expectations in order to reach agreement. Several rounds of negotiations may be involved as progress is made step by step. As was concluded by Ravnborg and Westermann (2002), joint learning provides a crucial and often essential basis for solving or ameliorating problems, and third party facilitation plays an important role in stakeholder identification, bringing conflicts and interdependencies into open and facilitating negotiations. Moreover, the understanding of the governance and cultural systems and the way they are structured and managed is also one point to be conscious of (Pahl-Wostl, Mostert and Tàbara, 2008). In negotiation mechanism, collaboration is underlined, and the negotiation model can be applied as the basis.

3. Incentive mechanism and regulatory mechanism. The incentive mechanism can help to realize that what the stakeholder wants to behave is just what the project or the society wishes to see. By designing a proper mechanism, the goal of the project can be achieved automatically by the individual optimization of each stakeholder, although it is often a second best solution as a whole. In the analysis, individual rationality and incentive compatibility should be taken into consideration. Individual rationality ensures that the participants are better off, and each one is willing to join the project. Incentive compatibility is the one that makes the individual voluntarily chooses what the society wants to see. But when reaching this outcome, individuals can get extra revenue due to their private information. This is why the best solution for the public is almost impossible to be obtained within the incentive mechanism. On the other side, regulatory mechanism will force stakeholders to keep their promises and make the negotiation process more effective. By supervision, constraints and punishment set by the public are good supplement to incentive mechanism. They limit the behaviors of stakeholders, and is conducive to reaching the point where social benefits are attained at the highest possible level.

4. Interest compensation mechanism. Interest compensation mechanism is the creative point and the essential topic in this paper, which is the key to the success of a project. It will be elaborated in a model in the following section. Based on the approaches shown above and under certain assumptions, it is to be proved that as long as the total revenue of the project is more than the total cost, it is possible to find a solution which is accepted by all stakeholders. In this way, Pareto improvement can be achieved with one round or several rounds of interest compensation. All stakeholders will either be better off or still hold their reservation utility.

5. Trust and sustainable development. In the operation, maintenance and renovation stages after the completion of the project, trust among stakeholders is the most important factor for a sustainable development. With no trust, things often get worse than they can be when people truly trust each other. An example that is usually mentioned is the monetary policy (Barro, 1986). When the authority betrays the public and chooses high inflation, it loses its authority in keeping inflation at a low rate and is less believed by the public. At this time, one monetary policy that aims to stimulate the economy may be ineffective and triggers high inflation, making the situation even worse. Reputation model can be used in solving the problem and dynamic game is introduced. The process involves adjustment of faith, which is determined by previous behaviors conducted by each stakeholder. In addition to rewards, punishment is also necessary to enhance trust and make the project more sustainable after completion. A mechanism ought to be designed in the way that stakeholders are aware that keeping promises is better than violating what is agreed on, thus reaching a better solution and building trust among people.

These five approaches are closely connected to each other, and cover the entire process of the project from the preparation stage to the operation and maintenance stage after completion. From the technique perspective, both cooperative games and non-cooperative games are utilized, and one approach may provide proper technique for another. For instance, the interest compensation mechanism is the core element in the analysis, which has to be based on the first three approaches, especially the disclosure of information, the incentive mechanism and the regulatory mechanism. Trust and sustainable development is formed upon the results of preparation and construction stages of the project, and is assisted by rewards and punishment methods derived from the regulatory mechanism.

3. Model for Compensation Mechanism

The model corresponds to the fourth approach in the last section and mainly applies and extends the Clarke-Groves mechanism, which provides a mechanism that makes stakeholders tell the truth in making decisions for public goods (Clarke, 1971; Groves, 1973; Mas-Colell, Whinston and Green, 1995; Myles, 1995).

In establishing the model, some differences are to be considered. In China, both administrative factors and economic mechanisms have significant influence on the strategic behaviors of the stakeholders, and pure economic model without considering the specific situations of China may not be feasible sometimes. The mechanism of information disclosure, incentive mechanism and negotiation mechanism mentioned in the previous section can be applied in solving problems of independent individuals, whereas stakeholders from China have particular characteristics resulted by the two

factors, thereby needing further discussion in a new scenario. Hence, interest compensation mechanism with comparison effect of strategic behavior among stakeholders is the key method in the analysis of stakeholders, and the behaviors of government sectors are involved when both administrative factors and economic mechanisms are taken into account. And the other mechanisms can play a role on the basis of the interest compensation mechanism.

In addition, previous theories often analyze stakeholders in a relatively independent way, and do not consider the effects imposed by the amount of transfer given to the other stakeholders. When one individual knows the amount of transfer received by the others, this individual may compare that amount to his or her own. Although sometimes the transfer is large enough, after one knowing that what he or she receives is less than what another person gets, this person will be dissatisfied. In this sense, the utility function is not only determined by the utility of the project and the absolute amount of the transfer, but it is also affected by the comparison among different individuals. This kind of effect is defined as comparison effect in the paper, and will be added in the model involving comparison effects.

3.1 Definitions

In the model for compensation mechanism, besides those definitions illustrated above that can be used in all five stages, a few definitions are to be given for this model:

(1) The final plan of the public project is x, which have many alternatives, and is determined by the strategic behaviors of each stakeholder s_i, for $i = 1, 2, \cdots, n$.

(2) The utility of stakeholder i is U_i, and it is assumed to take a quasi-linear form. The utility function is expressed as

$$U_i(x, \theta_i, e_i, t_i) = v_i(x, \theta_i) + (e_i + t_i) \tag{3.1}$$

for $i = 1, 2, \cdots, n$, where θ_i is the type of stakeholder i; v_i is the utility gained from the project, and is determined by the final plan x and the type of the stakeholder θ_i; e_i is the initial endowment of individual i or the reservation utility, which can be thought as the utility of holding a certain amount of currency or the utility gained from private goods bought by the same amount of currency, and e_i can be seen as a constant which will not have any influence on the maximization process; t_i is the transfer from the project to stakeholder i, and the transfer can be positive,

negative or just equal to zero, but the total transfer can not be positive since banks are also considered as stakeholders and it is assumed that there is no external source to raise funds, and is denoted as $\sum_{i=1}^{n} t_i \leq 0$. In the analysis, it is assumed that $\sum_{i=1}^{n} t_i = 0$.

3.2 Model analysis

For the entire project, the total revenue is the sum of the benefits gained by each individual who is better off from the project. As for the total cost, besides the construction and operation costs of the project, losses caused by the project to those who are worse off should also be considered. Stakeholders' benefits and losses are represented by v_i, for $i = 1, 2, \cdots, n$ as was mentioned in the definition part above. The goal of the project is to make everyone involved or affected become better off or at least do not get worse off (maintain their reservation utility), namely a Pareto improvement situation. In this sense, a basic condition is that the total revenue of the project must exceed the total cost of it, but this condition is not sufficient since those who enjoy the benefits and those who burden the costs are not the same stakeholders. Therefore, monetary transfer is needed among stakeholders. However, the question is how much the transfer should be for each stakeholder. Therefore, a mechanism for interest compensation is required as a way to answering the question. It is supposed that if the type of each stakeholder were known, it would be much easier to solve the problem according to v_i. Whereas, in reality, the type of stakeholders θ_i, for $i = 1, 2, \cdots, n$ or the information is kept by each individual and it is likely for them to speak out an untrue type to the public in order to gain more from the project, and this is denoted as $s_i \neq v_i$. In the following analysis, it is to be proved that there exists a mechanism that drives stakeholders to behave the same way as required for achieving social maximization.

For the entire project, the total revenue minus the total cost can be expressed as

$$\sum_{i=1}^{n} v_i(x, \theta_i) - C(x) \tag{3.2}$$

where $\sum_{i=1}^{n} v_i(x, \theta_i)$ contains both revenues and losses caused by the project to various stakeholders, and $C(x)$ is the construction and operation costs of the project. Equation 3.2 is the payoff function of the entire project, the maximization of which

indicates the social optimization. However, as the public does not know $v_i(x,\theta_i)$ and only knows $s_i(x,\theta_i)$, the maximization has to be done with

$$\sum_{i=1}^{n} s_i(x,\theta_i) - C(x) \tag{3.3}$$

The key to the mechanism is the establishment of the transfer function:

$$t_i = \sum_{\substack{j=1 \\ j\neq i}}^{n} s_j(x) - C(x) + r_i(s_{-i}) \tag{3.4}$$

for $i = 1,2,\cdots,n$, where $r_i(s_{-i})$ is a function that can be found in a specific circumstance to make the transfer function suitable for the mechanism, and the requirement is that its changes have no relevance with v_i or s_i, only depending on the strategies of stakeholders except individual i.

Therefore, the utility function of stakeholder i becomes (derived from Equation 3.1 and 3.4)

$$U_i(x,\theta_i,e_i,t_i) = v_i(x,\theta_i) + (e_i + t_i) = v_i(x,\theta_i) + e_i + \sum_{\substack{j=1 \\ j\neq i}}^{n} s_j(x) - C(x) + r_i(s_{-i}) \tag{3.5}$$

In the right side of the equation, e_i and $C(x)$ are constant, $\sum_{\substack{j=1 \\ j\neq i}}^{n} s_j(x)$ and $r_i(s_{-i})$ are decided by other individuals rather than stakeholder i. Hence, the only element that depends on individual i's choice is $v_i(x,\theta_i)$. Looking back at Equation 3.3 (the maximization process that is conducted by the public), if the individual wants to maximize its own utility function, the proper strategy should be telling the truth, that is $s_i(x) = v_i(x)$. The utility function can be changed to

$$U_i(x,\theta_i,e_i,t_i) = e_i + \sum_{i=1}^{n} s_i(x) - C(x) + r_i(s_{-i}) \tag{3.6}$$

In this equation, e_i and $r_i(s_{-i})$ do not depend on stakeholder i's decision, and $\sum_{i=1}^{n} s_i(x,\theta_i) - C(x)$ is maximized by the public. As a result, telling the truth is chosen by stakeholder i to maximize its utility function. In this way, each stakeholder i,

for $i = 1, 2, \cdots, n$, chooses the strategy "telling the truth", and Equation 3.2 is achieved, proving that this mechanism is able to solve the problem.

3.3 Model Involving Comparison Effects

Based on the model above, a small change exists after the comparison effects of stakeholders are introduced, which can show the utility change due to the comparison of transfer with the other stakeholders, especially those individuals who are alike. The new utility function is expressed as

$$U_i(x, \theta_i, e_i, t_i, t_{-i}) = v_i(x, \theta_i) + (e_i + t_i) + comp_i(t_i, t_{-i}) \tag{3.7}$$

Where $comp_i(t_i, t_{-i})$ represents the comparison effects and varies from person to person. In general, if stakeholder i finds the transfer t_i is smaller than the transfer of the other stakeholders who have similar characteristics, and finds the transfer is not sufficient after comparison, this individual will get negative utility in comparison effects, that is $comp_i(t_i, t_{-i}) < 0$; vice versa, $comp_i(t_i, t_{-i}) > 0$.

Next, consider the entire project. Since the comparison effects change the utility of individuals, the total revenue minus the total cost becomes

$$\sum_{i=1}^{n} v_i(x, \theta_i) + \sum_{i=1}^{n} comp_i(t_i, t_{-i}) - C(x) \tag{3.8}$$

The situation is similar in that the public does not know $v_i(x, \theta_i)$ and $comp_i(t_i, t_{-i})$. The public only knows the strategies chosen by each stakeholder. The strategy does not only include consideration of $v_i(x, \theta_i)$, but it also reflects $comp_i(t_i, t_{-i})$. The strategy chosen by individual i is now named as $s_i'(x, \theta_i)$, then the maximization of the public has to be done with

$$\sum_{i=1}^{n} s_i'(x, \theta_i) - C(x) \tag{3.9}$$

The transfer function is chosen as

$$t_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} s_j'(x) - C(x) + r_i'(s_{-i}') \tag{3.10}$$

for $i = 1, 2, \cdots, n$, where $r_i^{'}(s_{-i}^{'})$ is a function that can be found in a specific circumstance to make the transfer function suitable for the mechanism, and the requirement is that its changes have no relevance with v_i, $comp_i(t_i, t_{-i})$ and $s_i^{'}$, only depending on the strategies of other stakeholders.

Therefore, the utility function of stakeholder i becomes (derived from Equation 3.7 and 3.10)

$$U_i(x, \theta_i, e_i, t_i, t_{-i}) = v_i(x, \theta_i) + e_i + comp_i(t_i, t_{-i}) + \sum_{\substack{j=1 \\ j \neq i}}^{n} s_j^{'}(x) - C(x) + r_i^{'}(s_{-i}^{'}) \quad (3.11)$$

In the right side of the equation, e_i and $C(x)$ are constant, $\sum_{\substack{j=1 \\ j \neq i}}^{n} s_j^{'}(x)$ and $r_i^{'}(s_{-i}^{'})$ are decided by other individuals rather than stakeholder i. The elements that depend on individual i's choice are $v_i(x, \theta_i)$ and $comp_i(t_i, t_{-i})$. Looking back at Equation 3.9 (the maximization process conducted by the public), if the individual wants to maximize its own utility function, the proper strategy should be telling the truth, that is $s_i^{'}(x) = v_i(x) + comp_i(t_i, t_{-i})$. The utility function can be changed to

$$U_i(x, \theta_i, e_i, t_i) = e_i + \sum_{i=1}^{n} s_i^{'}(x) - C(x) + r_i^{'}(s_{-i}^{'}) \quad (3.12)$$

In this equation, e_i and $r_i^{'}(s_{-i}^{'})$ do not depend on stakeholder i's decision, and $\sum_{i=1}^{n} s_i^{'}(x) - C(x)$ is maximized by the public. It is proved that this mechanism is also incentive compatible when comparison effects are involved.

3.4 Policy Recommendation from the Comparison Effects

From the psychological side, when experiencing the same amount of changes in different directions, a person's utility change is often larger in the circumstance of losses than gains. For example, the degree of sadness caused by a loss of 100 units of currency is usually larger than the degree of happiness with a gain of 100 units of currency. As for comparison effects, it may be natural to reach the same conclusion. In the scenario of two people who are exactly the same in characteristics, person A receives more transfer than person B. After comparison, the increase of person A's utility by the comparison effect is smaller than the decrease of person B's utility by the comparison effect, and the total utility change caused by comparison effects is

negative. This can be extended when more people are considered. In consequence, $\sum_{i=1}^{n} comp_i(t_i, t_{-i}) < 0$ (considered in Equation 3.8) if inequality exists. As the degree of inequality increases, the value of $\sum_{i=1}^{n} comp_i(t_i, t_{-i})$ becomes smaller, thus decreasing the total utility of the entire project. In conclusion, when comparison effects are considered, inequality in interest compensation among different stakeholders reduces the total welfare of the project, and inequality should be avoided as much as possible. In practice, comparison effects are more obvious among residents than the other stakeholders, and this will be analyzed in the application later.

3.5 Conclusion of the Models

From the analysis above, it is proved that the interest compensation mechanism proposed is an incentive compatible mechanism that makes each stakeholder voluntarily choose to behave in accordance with the interest of the entire project when they are actually maximizing their own utility function. It should be noted that without knowing the type of each stakeholder, the public project is finally chosen as if the preferences of all stakeholders were uncovered and the project were determined for social maximization as a whole. In addition, during the entire process, the most important technique is the establishment of the transfer function, which is required not to be dependent on the strategy of stakeholder i. Meanwhile, the utility function and the social maximization target are somewhat overlapping, which partly results in an incentive compatible situation of the individuals. Within the models, the administrative factors can be analyzed by the involvement of government sectors, and the comparison effects are considered in the second model.

4. Applications

4.1 In a Water Project

Now consider a water project, for example, a water diversion project. Stakeholders can be divided into four categories: the government sector, residents, industries and other possible stakeholders. In each category, there are different stakeholders in the secondary level. Classification and behavioral characteristics will be discussed briefly, and a rough illustration of classification of stakeholders is shown in Table 2.

Table 2. Classification of Stakeholders.

Primary stakeholders	Secondary stakeholders
Governments	Central government, municipal government, relevant district and county governments, river basin management agency, Municipal Bureau of Water Resources, Municipal Bureau of Environmental Protection, legal entities of water resources projects, entities for project routine management and water supply companies
Residents	Urban residents, rural residents as water users and immigrants caused by building the project
Industries	The first industry, the second industry and the third industry
Other possible stakeholders	Banks, meteorological departments, meteorological departments, research institutes and non government organizations (NGOs)

1. Governments

The first primary category of stakeholders is governments. For the government sector, it is classified into nine stakeholders in the secondary level: central government, municipal government, relevant district and county governments, river basin management agency, Municipal Bureau of Water Resources, Municipal Bureau of Environmental Protection, legal entities of water resources projects, entities for project routine management and water supply companies.

The central government is responsible for making policies, laws and regulations for macro level water resources management, and the municipal government has the similar duties in a more micro level. Also, relevant district and county governments have even more micro responsibilities. Their utility functions are alike in aspects of financial income and expenditure, shares in power, satisfaction of residents and enterprises as well as social harmony and social stability. The municipal government and relevant district and county governments are also influenced by approval or critic from the upper level governments. The utility functions of other government agencies that are to be analyzed are also dependent on the evaluation from the upper level government sectors in different degrees, and this point will not be repeated in the following analysis. The river basin management agency is the representative agency of the Ministry of Water Resources. It implements water management for major water basins, but has no right to enact laws. Its target is to coordinate different stakeholders and follow the instructions of the central government. Municipal Bureau of Water Resources integrates three major sectors (water irrigation, water supply and drainage), allocates water resources and achieves unified management of the city’s water affairs.

Besides, Municipal Bureau of Environmental Protection is responsible for planning, implementation, management and control of environmental pollution and natural resources conservation. These two agencies pay more attention on the harmonious relationship between humans and nature. Legal entities of water resources projects are set up for the construction period, and are responsible for project quality, safety, schedule, funding and the use of funds. Entities for project routine management is responsible for management, surveying (including surveying and mapping), design, supervision and construction, etc. The last considered agency is water supply companies. They are responsible for construction, operation and management of water supporting projects and provide water supply to users. At the same time, they can cover the costs by charging water users and may receive transfer from the local governments. Here the water companies are supposed to be government controlled companies for the convenience of analysis, but more and more water companies are becoming private-owned enterprises.

For government sectors, $v_i(x,\theta_i)$ is the main concern, and is determined by their preferences to the outcomes of the water project. For instance, the central government may give the satisfaction of people and social stability high weights. t_i may be government transfers between different government sectors, or may be transfers to residents or industries. t_i can also be gains from specific taxes or penalties on some stakeholders.

2. Residents

Residents are roughly divided into urban residents, rural residents as water users and immigrants caused by building the project according to their different behaviors in general. Although water users are different even within the urban area or the rural area, they are not further divided for the convenience of analysis. If it is analyzed in a more specific way, more types of residents can be formed, which will make the analysis more like the reality. Urban residents may actually pay more taxes due to the construction of the water project, since large infrastructure projects often get subsidies from the government, and this is essentially paid by tax payers. Urban residents might also have to pay more for higher water price, but they can benefit from better water transport, more stable water supply, higher water quality and flood control, etc. All of these considerations can be put into the utility function, affecting $v_i(x,\theta_i)$ and t_i. Rural residents may suffer from taxes and increased costs from higher water price, but benefit from the improvement of rural water supply, which will add to their utilities.

Immigrants that are forced to leave their home lose utility for both economic and mental reasons, but they should be compensated with monetary transfer and other compensations which can be calculated in currency form, such as new houses or apartments, a better place for living, new working opportunities, etc.

Comparison effects are especially obvious in residents, and ought to be focused upon in empirical studies. First of all, various residents may have different function types for $comp_i(t_i, t_{-i})$. Some may feel extremely annoyed by inequality when their transfer is less than that of the others, and $comp_i(t_i, t_{-i})$ takes an important role in the utility function; whereas some may not be affected severely by the comparison effects. Therefore, in empirical analysis, methods from experiments and surveys may be utilized in finding different types of stakeholders and their proportion in a certain area. In consideration of the three types of residents, immigrants caused by building the project need the most concern. They are more sensitive to inequality, and may require higher interest compensation if the problem of inequality is serious. On one hand, higher interest compensation makes the project harder to realize and operate. On the other hand, some social problems and conflicts often arise when the problem of inequality is not treated in a right way.

3. Industries

Industries can be roughly classified into the first industry, the second industry and the third industry in a less detailed way. Without sufficient water, farmlands may suffer from droughts when rainfall is small or unevenly distributed in different time of the year or areas. But when a reliable water supply system is established, it will help the agricultural industry in times of droughts. Although production costs may rise due to higher water price as well as some construction costs for water facilities if it is necessary, stakeholders within the first industry benefit from eased water pressure, and the overall economic benefits are often improved. As for the second industry and the third industry, they also gain from eased water pressure, and are able to produce products and services in a more reliable way despite possible rise in water price.

For industries, the comparison effect may not be as significant as that of the residents. They pay more attention on the production process and profit maximization, and $comp_i(t_i, t_{-i})$ does not take up a high percentage in their utility function. For different industries and different sectors within an industry, various prices should be charged according to their amount of water consumption, and externality as well as the concept of water saving are to be emphasized.

4. Other possible stakeholders

Other possible stakeholders may include banks that offer loans and other financial services for the water project, meteorological departments, geographical departments, research institutes and non government organizations (NGOs) concerning different domains, for example, pollution prevention, environmental changes, animal protection or social equity. Banks get revenues from interests of loans and consulting fees for services, but also take risks for lending money to the water project. Meteorological departments, geographical departments and research institutes provide help in the appraisal of the water project and set rigid constraints with the help of relevant technology, and their advice are good for risk control, may reduce costs and alleviate possible conflicts for the project. Non government organizations (NGOs) are becoming an indispensible part for problem solving in social life. They can be seen as third parties that often supervise the process, uphold the interests of a certain group and find problems in a more independent perspective.

In the entire process of the water project, five approaches introduced above can be used for different stages of the project, from the preparation period of the project, the construction process, to the operation, maintenance and renovation stages after the completion of the water project. In the interest compensation aspect, the most critical concern is the transfer function of each stakeholder which ought to be set in the way demonstrated in the model section, and is independent from the stakeholder's own strategies. For some stakeholders, comparison effects have a relatively high weight, and should be paid much attention on.

4.2 Other Possible Applications

Apart from the water project like the water diversion project or a desalination project, the five approaches discussed in the paper, especially the interest compensation mechanism, can be taken into practice in many areas related to public or quasi-public goods and services. For instance, infrastructure projects are similar to the water project analyzed in the paper, and this can be used in the same way, such as electricity or energy plants and networks, communication facilities, highways and railways, city public transportation systems, etc. Besides, environmental protection and natural resources protection can also get hints from the mechanisms. Within a certain range, stakeholders need to pay for costs of protection and confine their own behaviors, but will benefit from better environment and the use of the improved environment and natural resources. In this process, the interest compensation mechanism is put into practice and gets everyone better off or at least not harmed from the program. In addition, other applications like basic cultural and educational services, scientific and technological development, the governance of market

disorders, protection of intellectual properties, anti-corruption (Wang, 2004) as well as other domains related to externalities and information asymmetry.

Although the range of application is vast, it should be noted that due to time, costs and effort constraints, the application of the proposed five approaches hasn't been put into practice for the time being and may encounter difficulties in practice, thereby needing further empirical research and analysis in the future.

5. Conclusion

As is illustrated in the introduction section, the role of integrated water resources management and stakeholder participation is of great importance. After getting insights from some literature on this issue, some methods can be applied in strategic behavior analysis of stakeholders in water resources management. Besides, the application of game theory can be seen as an alternative or a supplement. In the scenario of a water project, two aims are to be accomplished. One is people's harmonious relationship with the environment, which is a basic principle in making the project more sustainable in the future. The other aim is considered in the economic and social aspect, which emphasizes public participation and wants to make all stakeholders join the decision process and finally gain from the project or are at least not worse off. In order to achieve these two aims, five approaches from game theory are presented, and the fourth approach which is on interest compensation mechanism is elaborated in a model.

There are two categories with the provision of public goods: one is the specific items or projects such as street lights and parks; and another is the "open" public goods which can be unspecific things or materials like environment and institutions, the border issues of which such as the beneficiaries, utilities, construction costs and evaluation criteria are vague. Meanwhile, these may also vary with changes of participants or stakeholders as well as their organizational forms, and the marginal utility may increase as more participants are involved. In this paper, the issues of IWRM are more inclined to have features of the latter type, and the compensated mechanisms designed for IWRM can better solve the effective supply problem of public goods by attracting more participants and arousing the enthusiasm of various stakeholders to the maximum extent.

By applying the Clarke-Groves mechanism, one interest compensation mechanism for public project is found that makes each stakeholder tell the truth and finally realizes social optimization. The key element is the establishment of the transfer function, which motivates the stakeholders to behave in accordance with the interest of the entire project or the society. Since the administrative factors are important especially in China, these can be analyzed by the involvement of government sectors within the models. Meanwhile, a model including the comparison

effects are considered, which highlights the utility change caused by stakeholders' comparison in the amount of interest compensation. Thus, the framework of the analysis is a multi-stage, multi-stakeholder, multi-domain, multi-factor and multi-target game analysis process, and is extended in the comparison between stakeholders.

As for the application of the mechanisms, a water project is analyzed and the classification as well as their strategic characteristics is stated. Meanwhile, the five approaches especially the interest compensation mechanism can be used in other domains relevant to public or quasi-public goods and services. But it should be noted that the application hasn't been put into practice for the time being and may encounter difficulties in practice, thereby needing further empirical research and analysis in the future.

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