Advances in Economics, Business and Management Research, volume 56
3rd International Conference on Economic and Business Management (FEBM 2018)

Research on Prefabricated Building Promotion Based on Principal-Agent Theory

Linlin Hu
School of Economics and Management
Beijing Jiaotong University
Beijing,China
17120727@bjtu.edu.cn

***Abstract*—Based on the principal-agent theory, this paper establishes a model for the cost allocation of prefabricated building construction between the government and the construction units, and makes a quantitative analysis to determine the cost-sharing relationship of the participants; establishes a differential incentive mechanism for the government and construction units. It also gives suggestions and opinions on the government's practice of promoting prefabricated buildings.**

Keywords—Prefabricated; A principal-agent; An incentive mechanism

I. INTRODUCTION

The prefabricated building does not form economies of scale in China, combined with the cost of steam curing, storage, transportation and hoisting of prefabricated components, which makes prefabricated component cost higher, while the labor cost can be saved is limited by prefabricated buildings in China.[1] The high entry cost, unreasonable cost-sharing and uncertain external environment of the prefabricated construction market have reduced the participation enthusiasm of the construction enterprises.

This paper establishes the principal-agent model and quantitative analysis on the construction cost sharing between the government and the construction units, determines the variables that affect the effort and enthusiasm of the enterprises' participation in prefabricated construction market, and finds out the government's financial input to mobilize the enterprises' participation. The research of this paper not only helps the government and construction enterprises make scientific decision in the early stage of prefabricated construction, but also makes up the blank of the research on the cost sharing and incentive of the prefabricated building participants.

At present, foreign scholars' research on prefabricated building cost analysis mainly on the economic field, discusses the promotion of economic and social development of prefabricated buildings and the impact of the prefabricated building supply chain on its development, and discusses the supply Chain optimization problems. Domestic research on prefabricated construction cost analysis mainly starts from two aspects of example comparison and qualitative analysis, from the difference between prefabricated building and traditional cast-in-place construction cost to determine the main factors affecting the cost of prefabricated construction. Factors, from the overall macro perspective to summarize the factors affecting construction costs. According to the existing literatures, there are few researches on quantitative cost-sharing of prefabricated buildings, and the difference incentive mechanism among the participants is rarely mentioned.

II. THE COST ANALYSIS OF PREFABRICATED BUILDING PARTICIPANTS BASED ON THE PRINCIPAL-AGENT THEORY

The establishment of the principal-agent model is to analyze the optimal contract under the condition of asymmetric information. Reference [2] In the process of prefabricated building, the government policies and regulations are public information, the situation of construction units developing the prefabricated building is nonpublic information, and the two sides form the principal-agent relationship on the prefabricated building generalization. The cost-sharing analysis between the government and the construction units is to discuss the strength of the government incentive construction units to participate in the prefabricated building generalization.

Hypothesis 1: "a" is one-dimensional effort variable for the construction unit to adopt a prefabricated construction method, when "a" equals to zero means that the construction unit only uses cast-in-place construction.

The benefit output function brought by the prefabricated construction is linear: $\pi = \lambda \mathrm{a} + \theta, \lambda (\lambda \in R, 0 \leq \lambda \leq 1)$ is a benefit output factor related to the effort variable "a"; θ is a normal distribution random variable with a mean value of zero and variance σ^2, representing the external uncertainties.

Hypothesis 2: Assuming that the principal-Government is risk-neutral, the agent-Construction Unit is risk-averse. The incentive contract $S(\pi)$ formulated by the Government is composed of the fixed income α obtained from the original cast-in-place construction of the Construction Unit and government incentive subsidies when developing the productive output of prefabricated to reach π_0. Assuming the incentive factor is $\varphi(\varphi \in R, 0 \leq \varphi \leq 1)$, the incentive contract $S(\pi)$ is:

$$S(\pi) = \alpha + \varphi(\pi - \pi_0) = \alpha + \varphi\lambda(\mathrm{a} - \mathrm{a}_0) \qquad (1)$$

Hypothesis 3: Assuming that the utility function of Construction Unit has the invariant absolute risk aversion characteristic, i.e. $u=-e^{-\rho\omega}$. ρ is the absolute risk aversion metric and ω is the real monetary income.

Hypothesis 4: Assuming that the Construction Unit's effort cost $C(\mathrm{a})$ can be equivalent to the monetary cost, i.e. $C(\mathrm{a})=\frac{\beta \mathrm{a}^2}{2}$. β represents the cost factor.

As the Government adopts a risk-neutral strategy, the Government's expected utility is equivalent to the expected income:

$$Ev\big(\pi-S(\pi)\big)=E\big(\pi-S(\pi)\big)=-\alpha+(1-\varphi)\lambda\mathrm{a}+\varphi\lambda\mathrm{a}_0 \qquad (2)$$

From *Hypothesis 3*, the Construction Unit is risk-averse, the utility function has invariable absolute risk aversion characteristic $u=-e^{-\rho\omega}$, the actual income of the Construction Unit adopting the prefabricated construction is incentive contract (1) minus costs, as follows:

$$\omega=S(\pi)-C(\mathrm{a})=\alpha+\varphi\lambda(\mathrm{a}-\mathrm{a}_0)-\frac{\beta\mathrm{a}^2}{2} \qquad (3)$$

$$E(\omega)=\alpha+\varphi\lambda(\mathrm{a}-\mathrm{a}_0)-\frac{\beta\mathrm{a}^2}{2} \qquad (4)$$

The deterministic equivalent income of the Construction Unit is the expected value of the actual monetary income (3) of the Construction Unit minus the risk cost of income, i.e.

$$C_p=\alpha+\varphi\lambda(\mathrm{a}-\mathrm{a}_0)-\frac{\rho\varphi^2\sigma^2}{2}-\frac{\beta\mathrm{a}^2}{2} \qquad (5)$$

The participation constraints of the Construction Unit using prefabricated construction is that that deterministic equivalent income of the construction unit (5) is great than or equal to the minimum monetary income, this can be expressed as:

$$\alpha+\varphi\lambda(\mathrm{a}-\mathrm{a}_0)-\frac{\rho\varphi^2\sigma^2}{2}-\frac{\beta\mathrm{a}^2}{2}\geq\overline{\omega} \qquad (6)$$

Due to information asymmetry, the government will choose the effort level "a" of Construction Unit to develop the prefabricated building to maximize its own certain income (2). The incentive compatibility theory can be substituted by its first-order condition:

$$\frac{\partial C_p}{\partial \mathrm{a}}=(\alpha+\varphi\lambda(\mathrm{a}-a_0)-\frac{\rho\varphi^2\sigma^3}{2}-\frac{\beta\mathrm{a}^2}{2})'=0$$

Maximizing first-order conditions:

$$\mathrm{a}=\frac{\varphi\lambda}{\beta} \qquad (7)$$

The Government's problem is to choose φ to solve the following optimization problems:

$$\begin{cases}\max_{\varphi}(-\alpha+(1-\varphi)\lambda\mathrm{a}+\varphi\lambda\mathrm{a}_0)\\ s.t.(IR)\alpha+\varphi\lambda(\mathrm{a}-\mathrm{a}_0)-\frac{\rho\varphi^2\sigma^2}{2}-\frac{\beta\mathrm{a}^2}{2}\geq\overline{\omega}\\ (IC)\mathrm{a}=\frac{\varphi\lambda}{\beta}\end{cases} \qquad (8)$$

Substituting the participation constraint IR (6) and the incentive compatible constraint IC, that is the (7), into the objective function (8). The above optimization problems can be expressed as follows:

$$\max_{\varphi}(\frac{\varphi\lambda^2}{\beta}-\frac{\rho\varphi^2\sigma^2}{2}-\frac{\varphi^2\lambda^2}{2\beta}-\overline{\omega}) \qquad (9)$$

The first-order condition of φ for the above formula(9), as follows:

$$\varphi=\frac{\lambda^2}{\lambda^2+\rho\sigma^2\beta}>0 \qquad (10)$$

The above analysis means that the Construction Unit must bear a certain cost in the form of prefabricated construction, but the cost must be higher than $\overline{\omega}$, like (6). The income of Construction Unit received is not only related to the gains from the project, but also to government's incentives. Without considering the benefit of the project, this paper discusses the degree of effort "a" made by the Construction Unit to adopt the prefabricated construction method, and the degree of effort is related to the amount of reward obtained. The magnitude of incentive factor φ depends on the absolute risk aversion metric ρ, variance σ^2, effort cost β and the benefit output factor λ. In extreme cases, if the Construction Unit is risk-neutral($\rho=0$), the Government's optimal incentive contract requires the Construction Unit to bear all the investment risk.

To derive the (10), we can draw the following conclusions:

a. $\frac{\partial\varphi}{\partial\rho}=\frac{\lambda^2\sigma^2\beta}{(\lambda^2+\rho\sigma^2\beta)^2}<0$, that is the absolute risk aversion metric ρ is negatively correlated with incentive factor φ. Absolute risk aversion metric reflects the agent's attitude towards risk. At the current stage, in order to select excellent construction units to support, the Construction Unit self-development of prefabricated building capacity and level, the higher the ability and level of the Construction Unit to develop the prefabricated building itself, the more active and the take more risk in adoption of the prefabricated construction, the greater the government's subsidy.

b. $\frac{\partial\varphi}{\partial\sigma^2}=-\frac{\lambda^2\rho\beta}{(\lambda^2+\rho\sigma^2\beta)^2}<0$, that is the variance σ^2 of the distribution random variable θ is negatively correlated with incentive factor φ. The more interference the Construction Unit has, the lower the incentive to promote the prefabricated building. By reducing the external interference factors, the enterprise's initiative will increase, which is conducive to the promotion of prefabricated building.

c. $\frac{\partial\varphi}{\partial\beta} = \frac{\lambda^2\rho\sigma^2}{(\lambda^2+\rho\sigma^2\beta)^2} < 0$, that is the cost factor β of the Construction Unit's prefabricated construction is negatively correlated with the incentive factor φ. The greater the effort paid by Construction Units, the lower the cost factor. At this time the Government should increase the incentive factor φ, so that the Construction Units further promote the enthusiasm of developing the prefabricated building.

d. $\frac{\partial\varphi}{\partial\lambda} = \frac{2\lambda\rho\sigma^2\beta}{(\lambda^2+\rho\sigma^2\beta)^2} > 0$, that is the benefit output factor λ is positively correlated with the incentive factor φ. The greater the benefit output factor λ, the more the Construction Unit invests in technology and construction management, and the greater the risk of sharing by Construction Unit. At this time the Government needs to use a higher incentive factor to reward the Construction Units in the development of prefabricated construction efforts.

In a word, ρ, σ^2 and β are negatively correlated with the incentive factor φ obtained by the Construction Unit by prefabricated construction. The larger ρ, σ^2 and β are, the smaller the incentive factor φ is. The benefit output factor λ is positively related to φ, and the larger the λ, the more rewarding for the development of the prefabricated building will be. If the Government can formulate a suitable incentive factor φ can guide the Construction Units' effort level to participate in the promotion of prefabricated building. According to the above analysis, the optimal cost-sharing incentive factor is $\varphi^* = \frac{\lambda^2}{\lambda^2+\rho\sigma^2\beta}$, the maximum effort level is: $a^* = \frac{\lambda^3}{\beta(\lambda^2+\rho\sigma^2\beta)}$

In order to motivate the Construction Units to participate in the prefabricated building promotion, the Government should formulate appropriate incentive policy and supervision mechanism. The following suggestions can be drawn from the model analysis: a. Establish the lowest assembly rate and target of the industry; b. The difference incentives for different enterprises; c. Good social environment is conducive to the promotion of prefabricated building; d. Develop transparent and impartial supervision mechanism; e. Recognize industry trends and policy advocacy; f. Actively promote and stimulate demand expansion.

III. Differential Incentive Mechanism

A. Incentive Mechanism for Construction Units

As an independent market economy activist, the Construction Unit mainly pursues the maximization of economic benefits. The Government should guide the Construction Units to participate in the development of prefabricated buildings from the perspective of their own interests, to align the economic efficiency objectives of the enterprises with the social goals of the Government, and to establish and improve effective incentive mechanism. The incentives are usually classified into two types: economic incentives and non-economic incentives.

The Government can use the enterprises' preference for economic interests and use the economic means to motivate the Construction Units. For example, to reduce the price of the component by tax deductions or concessions, tilting on credit approval and project review of prefabricated projects, economic incentives for special subsidies or floor-to-rate incentives for qualified prefabricated projects.

The Government should reasonably share the construction cost of the development of the prefabricated building. According to the model analysis, only when the Government's incentive intensity is greater than or equal to $\varphi = \frac{\lambda a+\sqrt{(\lambda a)^2-4(\frac{\lambda^2}{2\beta}-\rho\sigma^2)(\alpha-\bar{\omega})}}{2(\frac{\lambda^2}{2\beta}-\rho\sigma^2)}$, the Construction Units will take prefabricated construction for economic benefits.

The use of economic incentive alone not only increases the Government's financial burden, but also weakens the social responsibility consciousness of the Construction Units. Non-economic incentives refer to intervention or regulation of behavior of participating subjects through laws, regulations, policies and administration means. In view of the present situation of China's prefabricated building, the main ways of non-economic incentives are: a. To formulate the relevant laws and regulations of prefabricated buildings; b. To regulate the construction process of prefabricated buildings; c. To market operation, supplemented by policy support

B. Incentive and Restraint Mechanism for Government

The theory of Public Choice argues that based on the economic man, the political economic groups with the government as the carrier is analyzed as rational economic person. It can explain the public choices of the government and study how the public expresses its willingness to decide on the supply of public goods or service.

In order to ensure the fairness and validity of the laws and regulations enacted by the government for the promotion of prefabricated buildings, the study of government behavior supervision and incentives and constraints are as follows: a. Strengthening the significance of the rule of law government; Reference [3] ; b. Optimizing governmental organization structure; c. Rationally utilizing the government's "Rational Economic Man" characteristics.

C. Conclusion and Prospect

This paper constructs a principal-agent model of cost sharing for prefabricated building, analyzes the influence of different variables on the proportion of cost sharing under the existing conditions, studies and determines a reasonable proportion of cost sharing, and puts forward a differential incentive mechanism based on different participants and development stages.

There are still many shortcomings in the research of this paper: a. In the quantitative analysis model, the nonlinear relationship between benefit output and effort cost is not analyzed, and the generalization model is lacking; b. The research is only theoretically discussed, no case verification; c. The future development of the prefabricated building is not analyzed; d. The differential incentive mechanism lacks practical data support and quantitative analysis.

REFERENCES

[1] Z. Li, Y.Z. Ren, and Q.D. Dai, "Analysis of the problems and prospects of national promotion of prefabricated buildings," China Housing Facilities, vol. 2, pp.19-21, 2016, DOI: 10.3969/j.issn.1672-5093.2016 .02.005.

[2] W.Y. Zhang, Game Theory and Information Economics, Shanghai: Shanghai People's Publishing House, 2004.

[3] Y. Huang, Research on China's public policy formulation system from the perspective of public choice theory, Dissertation of Hunan University, 2008.