




Ecological Administration Contract Design for Enterprise and Local Government Based on Bottom-Line Thinking

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Abstract. Based on the perspective of ecological bottom-line thinking, government administration and corporate manufacturing are a new kind of cooperation instead of the relationship between cat and mouse. The corporate and the government are committed to sustainable economic development in the context of ecological and environmental protection. The ecological value preference parameters are introduced in the classic incentive contract model, and the improved incentive contract is constructed in the framework of ecological bottom-line and economic sustainable development thinking of government administration and corporate social responsibility, and the model equilibrium is analyzed. Finally, a numerical example is constructed to verify the correctness of the conclusion. The research results show that the introduction of ecological value preference parameters can effectively coordinate the interests of government and corporate, and control incentive costs; the ecological value preference of government and corporate, the marginal output of corporate and risk aversion will affect the change of incentive contracts.

Keywords: Bottom-line thinking · Government administration · Contract design

1 Introduction

Since the reform and opening up, with GDP as the main economic assessment indicator and the values of pollution before treatment, the demand for natural ecology far exceeds its carrying capacity. In some areas, local resources are being developed arbitrarily, and the relationship between economic development and ecological environmental protection has not been handled properly. Economic development has been traded at the expense of unrestrained consumption of resources and environmental damage, result in increasingly prominent energy resources and ecological environmental problems. Some areas do not hesitate to touch the ecological bottom line and have achieved short-term high-speed economic growth at the expense of the natural environment. However, due

to high resource consumption and heavy environmental pollution, which caused serious pollution of water bodies, the atmosphere or soil, urban haze weather has become the norm. The serious imbalance of natural ecosystems has become a serious problem for sustainable economic development. Facing the severe situation of intensified resource and environmental constraints, ecological environment pollution and ecosystem degradation, we must re-examine and coordinate the relationship between ecology and development.

Under the environmental governance system, it must emphasize and establish the ecological development concept of Lucid waters and lush mountains are invaluable assets, building an environmental administration system in which the government dominates, enterprises as the main body, social organizations and the public participate together, and improving the ecological environment Management system to resolutely stop and punish acts that damage the ecological environment. The economic development model based on development and ecological bottom line thinking reflects the value orientation and ecological ethics of ecological civilization construction. The economic development mode based on the bottom-line thinking means controlling economic construction activities within the range that the natural environment can bear, advocating the construction of ecological civilization, promoting the transformation of economic development pattern, and combine ecological environmental protection with the optimization of the spatial distribution of productivity to form a spatial structure of resource-saving and protecting environment. We will insist on building an environmentally-friendly economy and sustainable development with low cost, high efficiency, low emissions.

Under circumstance of the new normal of economic development, the government should not only ensure sustained and rapid development of economic construction in accordance with the established goals, but also enable enterprises to obtain considerable economic benefits, While achieving economic benefits, enterprises do not sacrifice the ecological environment at the expense of the ecological environment, but also promote the restoration and protection of the ecological environment system. We intend to introduce preference parameters of corporate social responsibility, and discuss the long-term mechanism design of sustainable economic development in the context of corporate social responsibility and government governance from the perspective of keeping the bottom-line of economic development and ecological protection. On the one hand, enterprises should bear the corporate social responsibility to protect the environment, and can obtain considerable economic benefits without touching the ecological bottom-line. On the other hand, the government should strengthen the ecological environment management, which not only can protect the ecological environment system, but also ensure the economy runs smoothly, safely and sustainable.

The paper is organized as follows. In Sect. 2, we review the literature regarding bottom-line thinking involving development and conservation of ecosystem between enterprise and government. We not only discuss the difference of ecological bottom-line and ecological bottom red line but also the game between enterprise and government. We have built contract model and assumption in Sect. 3. We analyzed the model and discuss influence on parameters in Sect. 4. The validity of model is verified with a numerical example and simulation in Sect. 5, and we conclude in Sect. 6.

2 Literature Review

Bottom-line thinking is a kind of strategic thinking, a thinking method and mentality bottom-line-oriented. It is an insurmountable critical line, critical point or critical area that the main body set according to his own interests, emotions, morals, and laws. It will lead to qualitative changes in attitudes, positions and decisions once the main body crosses the bottom-line (Louwei 2015). Bottom-line thinking points out possible risks and worst-case scenarios, and makes scientific judgments through systematic thinking, then keeps the bottom-line and pursues the best results of the system. It not only warns people to take precautions, carefully evaluate development risks, but also guides people to be mentally prepared to turn challenges into opportunities and passive to active, pursues the best results from the worst, and pursue the most optimized results while keeping the bottom-line, in order to achieve the best results and better established goals (Zou et al. 2015).

The bottom-line thinking is applied to the construction of ecological civilization, that is, the ecological bottom-line. It refers to the ecological security line that cannot be broken out. It is the minimum standard for maintaining basic regional ecosystem and ecological security. It is not only including a synthetic system that maintaining basic ecosystem services, the security pattern of hydrological regulation, climate regulation, water supply, and biodiversity protection, but also including the bottom-line of ecological function, environmental quality and safety, and natural re-source use, etc. (Liu 2015) Similar to the ecological bottom-line, there is also the ecological red line. Whether it is the ecological bottom line or the ecological red line in the perspective of connotation, it is the lifeline of ecological security, public health, sustainable development, and the ecological environment. Ecological red-line is a legal or institutional management tool with legally binding protection for the ecological bottom-line and restricts acts that damage ecosystems. Therefore, the ecological bottom-line more reflects the load-carrying limit of the natural system itself, and the ecological red-line is a kind of protection line set by the law and helping to keep the ecological bottom-line, it is the legal basis for investigating the legal responsibility for destroying the ecological environment (Wenzhi 2016).

Many scholars have studied the relationship between ecological environmental protection and economic development from different perspectives. For example, Peter Vandergeest et al. (2012) believe that transnational ecological certification can strengthen global ecological protection. The education policy of sustainable ecological-centered proposed by Gorobets A (2014) that can shape people's mentality and behavior, rather than dominate the current Economic growth model to avoid systemic global environmental problems. Zhang Wei et al. (2011) believe that a platform for government-business cooperation should be established to provide a green technical support system and financial services, support the construction of ecological civilization, incorporate ecological civilization indicators into the performance evaluation of government, and strengthen ecological civilization legislation. DeCanio S J et al. (2013) applied game theory to study the issue of climate diplomacy, discusses the prisoner's dilemma, the cock-fighting game and so on by constructing the 2 x 2 game model, intergovernmental negotiations depended on the severity of climate change risks. Shaoqing Chen et al. (2013) Proposed a comprehensive ecosystem-oriented risk assessment, which is helpful for environmental

management. Korhonen J (2004) studied strategic decisions for sustainable development from the perspective of industrial ecology, and promoted industrial ecological integration through ecological economics and environmental management. Boland A et al. (2012) Studied the public participation of community-based environmental protection activities, and discussed the incentive structure of project organizers and participants for China's green community activities.

However, Chinese scholars research the strategic games among government, enterprises and environmental protection departments from the perspective of game theory. Chuanjiang Liu (2014) believes that the essence of the environmental pollution problem in the new urbanization construction is the result of a game of the four main interests of the central government, local governments, enterprises and farmers. Like Wang (2016) believes that the primary task of the local government's environmental pollution prevention and control policy reform is to break through the complex interest entanglements. Xu Lin (2016) used dynamic game theories to establish the game models of government and polluting companies, polluting companies and insurance companies, respectively, Research conclusions show that to break through the plight of environmental pollution responsibility, the government should improve environmental legislation as soon as possible, strictly enforce the law, and provide insurance companies and insurance companies with Appropriate subsidies. Li Bin's (2015) research shows that the expansion of land finance scale has exacerbated environmental pollution, and economic growth, urbanization and energy efficiency are reasons of environmental pollution. Sunzhe Wong (2018) believes that the distortion of incentives will lead to poor government supervision, and setting strict responsibilities can reduce incentives. Wenbing Luo et al. (2015) believed that the establishment of a total emission control and distribution mechanism for pollutants in river valleys could strengthen the prevention and control of water pollution. Sun han's (2015) research shows that the government's environmental supervision and related policy support is an important means to promote water pollution control in the western minority areas. Studies such as Fengxia Han et al. (2017) believe that the government should increase penalties for non-environmental protection behaviors, and enterprises should carry out green design and production, change production mode and protect the ecological environment through the support of green finance. Tong Yan (2016) believes that reasonable rules and technological innovation should be established to reduce pollution costs. Wang Xianjia (2018) used the evolutionary game to coordinate the path of environmental governance by considering the benefit coefficient, cost and vision level. Liao Qi et al. (2019) Proceeded from the protection of the ecological barrier in Hu-bei, which believed that the battle against pollution prevention and control should be done well and the ecological environment safety should be continuously improved. Zheng Jianxia et al. (2017) Studied the planning innovation and institutional breakthroughs in the transition from ecological priority to ecological control from the aspects of ecological protection red line planning, concept definition, red line delineation, and policy control in Ningbo.

Based on the above comprehensive analysis, there are many studies on ecological environment issues, there still exist some problems: some scholars mainly focus on ecological environmental protection, industrial ecology and global ecological issues from a perspective of macro level, while the others scholars research eco-environment

issues from a perspective of micro-level, for example, mainly focus on game theory between government and enterprises. Which protects the ecological environment through environmental policies, environmental legislation and punitive measures.

None of the above studies think about bottom-thinking from the perspectives of development, ecology and corporate social responsibility. We intend to establish a contract based on corporate social responsibility (CSR) and government management from the framework of development and ecological bottom-line thinking and corporate social responsibility, the essay introduce CSR value preference parameters into the contract, to discuss impacts of contract resulted from value preference parameter of the government, marginal output of enterprise unit effort based on CSR and risk aversion attitude of the enterprise. The government and enterprises will change the traditional game “cat chases for mice” through cooperation and creation, they are no longer conflicting. The government supports enterprises with technological reforms and industrial upgrading. Based on the corporate social responsibility, applying bottom-line thinking, the enterprise obtains economic benefit through developing green economy, recycling economy and other ecological economy methods, the government achieves good political performance through green GDP.

3 Model Assumption and Establishment

Within the framework of development and ecological bottom-line thinking, both governments and enterprises will consider their own benefits in long run, the government requires enterprises to fulfill their corporate social responsibilities and create more economic value and social value without touching the ecological bottom-line or ecological red-line. In order to obtain long-term benefits, enterprises generally also perform corporate social responsibilities and carry out production in the conditions of protecting the ecological environment system in accordance with the requirements of the government to govern the environment. When enterprises transform from destructive production to ecological economy or implement environmental protection measures, it is generally necessary to experience technological reform & industrial structure upgrading and input manpower and financial & material resources of large quantity, which increases production and management costs with reduced operation profit, and so, enterprises have no motivation to perform actively their corporate social responsibilities and participate in ecological environment construction. Therefore, in order to the government will take measures to curb environmental pollution. Therefore, government will provide political and fund supports for enterprises, stimulating them to input on environmental protection and ecological civilization construction, so as to ensure the normal operation and sustainable development of the economic and social development as well as to protect the ecological environment system from damage.

To explain game behavior between government (G) and enterprise (E), assumptions are hereby made as follows:

Assumption 1. To make convenience for problem discussion without loss of generality, it is assumed that enterprise should transform from destructive production to sustainable ecological economic production based on bottom-line thinking, the benefits created through ecological economic construction or transformation as $w = re + \varepsilon$. Where, e

refers to effort level made by enterprises to meet requirement of ecological economic transformation (including the input of manpower, financial resources, material resources, technical reform and structure upgrading, etc., For the convenience of the discussion, the following efforts are the same as those expressed here) based on corporate social responsibilities. $e \in [0, +\infty)$; r refers to marginal output made by enterprises working on ecological economy, which subject to effort level of enterprise, ε refers to exogenous and independent random variable. It is assumed that random variable should comply with $N(0, \sigma^2)$ distribution.

Assumption 2. It is assumed that in order to stimulate enterprise to undertake corporate social responsibilities and engage in ecological economic construction, the government should provide enterprise with linear mixed incentive contract $s = \alpha + \beta w$. Where: α refers to fixed compensation provided by government to compensate enterprise for ecological economic construction investment and carry out corporate social responsibilities; $\beta \in [0, 1]$ refers to distribution coefficient provided by government for enterprises working on ecological economic construction and creating value (it is assumed hereof that government should distribute earnings with enterprises through fiscal taxation); larger β indicates less tax collected by government from enterprises and more support of government for enterprise, and vice versa. When α is 0, it indicates that government provides performance contract; when β is 0, it is fixed contract. Meanwhile, effort cost function of enterprise is assumed as $C = be^2/2$, where b refers to effort cost coefficient of enterprise. Effort cost of enterprise is related to effort level e , with $C'(e) > 0, C''(e) > 0$. Namely, C is the strictly convex function of e . With effort level e increasing, effort cost C increases more rapidly.

Assumption 3. Assuming the government is risk-neutral and enterprise is risk-averse; the absolute risk- aversion measurement of $\rho > 0$, risk cost should be $\rho\beta^2\sigma^2/2$.

According to the above assumption, certain equivalence income of enterprise is

$$CE_E = \alpha + \beta re - be^2/2 - \rho\beta^2\sigma^2/2$$

Assumption 4. As the regulator, government shall consider both long-term interest of ecological environmental protection & sustainable development and value creation of enterprise interest during the process of decision making, ensuring economic and social sustainable development. Furthermore, without loss of generality, reservation utility of enterprise is assumed as $\tilde{u} = 0$.

Based on the above assumptions, the decision-making behavior of government can be expressed as:

$$\max_{\alpha, \beta, e} EU_G = (1 - \lambda)[(1 - \beta)re - \alpha] + \lambda re \tag{1}$$

$$s.t. (IR)\alpha + \beta re - be^2/2 - \rho\beta^2\sigma^2/2 > \tilde{u} \tag{2}$$

$$(IC)e \in \arg \max \alpha + \beta re - be^2/2 - \rho\beta^2\sigma^2/2 \tag{3}$$

Where, $\lambda \in [0, 1]$ is the ecological value preference parameter of government; when $\lambda \rightarrow 1$, government pays more attention to GDP that creation of enterprise for the government

and allows the enterprise to destroy the ecological environment for production. When $\lambda \rightarrow 0$, it means that government prefers to focus on the protection of the ecosystem and sustainable development of economic construction considering ecological bottom-line thinking. Promoting the upgrading of industrial structure, industrial transformation to protect the environment with incentive measurement.

4 Model Equilibrium and Analysis

4.1 Model Equilibrium

Backward induction is applied to solve game equilibrium between government and enterprise based on development and ecological bottom-line thinking underneath. Since incentives and constraints cannot be constrained under complete information conditions, government governance can force companies to execute contracts. Therefore, for the optimal problem (1), in the equilibrium state, the constraints in formula (2) are tight. Namely, the following formula comes into existence:

$$\alpha + \beta re = be^2/2 + \rho\beta^2\sigma^2/2 + \tilde{u}$$

Substituting the above formula into the objective function (1):

$$\max_{\alpha, \beta} re - (1 - \lambda)(be^2/2 + \rho\beta^2\sigma^2/2 + \tilde{u}) \tag{4}$$

Furthermore, calculate the first-order optimal condition of the effort level in formula (3):

$$e = \beta r/b \tag{5}$$

Substituting formula (5) into formula (4), and calculate β the first derivative, we get the optimal benefit distribution coefficient of government and enterprises based on bottom-line thinking to encourage enterprises to protect the ecological environment and implement industrial structure upgrade and transformation:

$$\beta^* = r^2/(1 - \lambda)(r^2 + b\rho\sigma^2). \tag{6}$$

Substituting formula (6) into formula (5), we can get the optimal effort level of the enterprise:

$$e^* = r^3/(1 - \lambda)b(r^2 + b\rho\sigma^2). \tag{7}$$

According to the conditions of β^* , e^* and formula (2), the optimal incentive compensation given by the government can be calculated as:

$$\alpha^* = \left[r^4(b\rho\sigma^2 - r^2)/2(1 - \lambda)^2b(r^2 + b\rho\sigma^2)^2 \right] + \tilde{u} \tag{8}$$

Where, when $\alpha^* < 0$ at $b\rho\sigma^2 \leq r^2$ indicates the enterprise would be required to pay the government the protection costs caused by environmental damage for production, and the government would pay the funds for ecological environmental protection;

when $\alpha^* \geq 0$ at $b\rho\sigma^2 \geq r^2$ indicates the government will compensate the enterprise amount of expenses to support technological transformation, upgrading and other investment, encouraging enterprises protect the ecological environment which is conducive to sustainable economic development based on development and ecological bottom-line thinking.

4.2 Model Analysis

To discuss the win-win cooperation mechanism between the government and enterprise from the perspective of bottom-line thinking, the other exogenous parameters involved in the fixed standard model remain the same. Now analyzing ecological value preference parameters of government's, marginal output of efforts and risk aversion attitudes, discussing the impact of these variables on contract parameters, performance, optimal effort levels, and costs.

4.2.1 Analysis of Contract Parameters

Proposition 1. Given that the model and other parameters are invariable:

- 1) With λ increasing, the government will provide enterprise with higher income distribution coefficients and compensation for transformation and upgrading. Affected by the contract adjustment, the optimal effort level of enterprise will improve and the total revenue w will increase.
- 2) With r increasing, for $0 < r^2 \leq 0.5616b\rho\sigma^2$, the government will enlarge the distribution coefficient and compensation of enterprises to ensure that enterprises protect the ecological environment based on bottom-line thinking. When enterprise marginal output meets $0.5616b\rho\sigma^2 < r^2 \leq b\rho\sigma^2$, government will further increase distribution coefficient of enterprise and reduce fixed compensation α to regulate enterprise income. Under the influence of contract modification, the optimal effort level of enterprise will increase with marginal output r increasing.
- 3) With ρ increasing, the income distribution coefficient of the enterprise will decrease. Affected by contract modification, the effort level of enterprise will decrease too. When $\rho \in (0, 3r^2/b\sigma^2)$ condition is satisfied, the government will only reduce the distribution coefficient of enterprises, but does not reduce fixed compensation for enterprises. When $\rho \in (3r^2/b\sigma^2, +\infty)$ condition is satisfied, government will decrease both enterprise distribution coefficient and fixed compensation.

Proof. Let's prove the conclusion (1) in proposition 1. Fix other parameters invariable and calculate first-order derivative of λ in formula (6)~formula (8):

$$\partial\beta^*/\partial\lambda = r^2/(1 - \lambda)^2(r^2 + b\rho\sigma^2) > 0$$

$$\partial e^*/\partial\lambda = r^3/(1 - \lambda)^2b(r^2 + b\rho\sigma^2) > 0$$

$$\partial\alpha^*/\partial\lambda = r^4/(1 - \lambda)^3b(r^2 + b\rho\sigma^2)^2 > 0$$

It can be inferred from the derivation result that β^* , e^* and α^* increase with λ increasing. It is obviously knowable in combination with formula $w = re + \varepsilon$ that total revenue w will increase with effort level e increasing.

Let's prove the conclusion (2) in Proposition 1, and similarly, calculate first-order derivative r in formula (6)~formula (7):

$$\frac{\partial \beta^*}{\partial r} = \frac{2rb\rho\sigma^2}{(1-\lambda)(r^2+b\rho\sigma^2)^2} > 0, \quad \frac{\partial e^*}{\partial r} = \frac{r^2(r^2+3b\rho\sigma^2)}{(1-\lambda)b(r^2+b\rho\sigma^2)^2} > 0$$

The result of derivation indicates that β^* and e^* increase with marginal output r increasing.

Formula (8) calculates first-order derivative for r

$$\frac{\partial \alpha^*}{\partial r} = -\frac{\lambda^2 r^3 [r^4 + 3b\rho\sigma^2 r^2 - 2b^2 \rho^2 \sigma^4]}{(1-\lambda)^4 b (r^2 + b\rho\sigma^2)^3}$$

Obviously, symbol of $\partial \alpha^* / \partial r$ is subject to $\varphi(r) = r^4 + 3b\rho\sigma^2 r^2 - 2b^2 \rho^2 \sigma^4$. Solve $\varphi(r)$ and reach the following conclusion:

$\partial \alpha^* / \partial r > 0$ at $r^2 \in (0, 0.5616b\rho\sigma^2]$, it can be known through $\partial \beta^* / \partial r > 0$ that government will increase enterprise distribution coefficient and fixed compensation to ensure that enterprises protect ecological and cleaner production; $\partial \alpha^* / \partial r < 0$ at $r^2 \in (0.5616b\rho\sigma^2, b\rho\sigma^2]$, it can be known through $\partial \beta^* / \partial r > 0$ that government will further increase enterprise distribution coefficient, and will reduce fixed compensation α to regulate enterprise income; conclusion (2) in proposition 1 comes into existence according to $\partial e^* / \partial r > 0$.

For the conclusion (3) in Proposition 1, calculate first-order derivation for formula (6)~formula (7):

$$\begin{aligned} \frac{\partial \beta^*}{\partial \rho} &= -\frac{r^2}{(1-\lambda)} \cdot \frac{b\rho^2}{(r^2+b\rho\sigma^2)^2} < 0 \\ \frac{\partial e^*}{\partial \rho} &= -\frac{r^3}{(1-\lambda)b} \cdot \frac{b\rho^2}{(r^2+b\rho\sigma^2)^2} < 0 \\ \frac{\partial \alpha^*}{\partial \rho} &= \frac{\sigma^2 r^4}{2(1-\lambda)^2} \cdot \frac{(3r^2-b\rho\sigma^2)}{(r^2+b\rho\sigma^2)^3} \end{aligned}$$

$\partial \alpha^* / \partial \rho > 0$ at $3r^2 - b\rho\sigma^2 > 0$, namely: $0 < \rho < 3r^2/b\sigma^2$; $\partial \alpha^* / \partial \rho < 0$ at $3r^2 - b\rho\sigma^2 < 0$. Conclusion (3) shows that there is a certain interval for the risk aversion measures of enterprises. Within the interval, the government will only reduce the distribution coefficient, but will not reduce the level of fixed compensation. When outside the interval, the government will reduce both the distribution coefficient and fixed compensation, and even levies environmental protection costs on the enterprise.

Proposition 1 illustrates that the optimal effort level, distribution coefficient, and fixed compensation provided of the government for the enterprise based on bottom-line thinking for ecological civilization production are functions of the government's ecological value preference parameters, the enterprise's marginal output, and risk aversion

parameters. When the government encourages enterprises to transform and upgrade to engage in ecological economic construction ($\lambda \rightarrow 1$) based on bottom-line thinking, they will provide enterprises with a higher income distribution coefficient and fixed compensation. Affected by government incentives, enterprise will improve their level of effort in upgrading and transformation, and at the same time, their total revenue will increase. When the marginal output of unit effort increases, the government will simultaneously by transforming incentive method of increasing distribution coefficient and fixed compensation to the method of enterprise performance level. At the same time, the enterprise will improve and maintain higher level of effort. When the enterprise risk aversion attitude increases, namely to reduce investment in environmental protection and ecological economic construction, the government will reduce the performance income of the enterprise, and levy more taxes on environmental protection expenses. When enterprise risk aversion level is within the expectation of government, it will only decrease distribution coefficient, and will not reduce fixed compensation for enterprise; if it exceeds expectation of government, it will reduce both distribution coefficient and fixed compensation of enterprise. Enterprise is enforced to carry out technological transformation and industrial upgrading based on bottom-line thinking through reverse incentives.

4.2.2 Economic Benefit Analysis

Proposition 2. Given the model and other parameters are invariant, and the following conclusions may be drawn:

- 1) As the value preference parameter λ increases, the economic output of enterprises will increase while revenue (mainly tax) of government will decrease. When $\lambda \in (0, 1/2)$, income of government is positive with per unit increasing income of enterprise greater than that of government. When $\lambda \in (1/2, 1)$, income of government is negative with per unit increasing income of enterprise less than that of government.
- 2) As the marginal output r increases, the economic output of the enterprise will increase. When $0 < \lambda < 1/2$, the government's certainty income will increase as r increases; when $1/2 \leq \lambda < 1$, certain income of government will decrease as r increases.
- 3) As risk measurement ρ increases, the economic output of the enterprise will decrease. When $\lambda \in (0, 1/2)$, certain income of government will decrease as ρ increases; when $\lambda \in [1/2, 1)$, certain income of government will increase as ρ increases.

Prove. Proving conclusion (1) Firstly. Based on formula (6)~formula (8), calculating the economic output of enterprise and certain income of government respectively as following:

$$Ew = re^* = r^4 / (1 - \lambda)b(r^2 + b\rho\sigma^2) \tag{9}$$

$$CE_G = (1 - \beta^*)re^* - \alpha^* = \left[r^4(1 - 2\lambda) / 2(1 - \lambda)^2b(r^2 + b\rho\sigma^2) \right] - \tilde{u} \tag{10}$$

Calculating first derivative for formula (9) and formula (10) concerning λ :

$$\partial Ew/\partial \lambda = r^4/(1 - \lambda)^2 b(r^2 + b\rho\sigma^2) > 0,$$

The results show that Ew will increase with λ increasing and decrease with λ decreasing. In other words, the economic output of enterprises will increase while the government's certainty revenue will decrease. If set $\tilde{u} = 0$ and $CE_G = 0$ then $\lambda = 1/2$. Since $|\partial Ew/\partial \lambda/\partial CE_G/\partial \lambda| = 1 - \lambda/\lambda$, for any $0 < \lambda < 1/2$, $CE_G > 0$, $1 - \lambda/\lambda > 1$ indicates that income of government is positive but per unit increasing income of enterprise is greater than that of government. For any $1/2 < \lambda < 1$, $CE_G < 0$, $1 - \lambda/\lambda < 1$ indicates that income of government is negative and per unit increasing income of enterprise is less than that of government. At this moment, government not only obtains no tax revenues from enterprise but gives funding to ecological economic construction of enterprise which are used for upgrading and technological transformation for environmental protection construction.

Next proving the conclusion (2). Calculating first derivative for formula (9) and formula (10) concerning r respectively:

$$\begin{aligned} \frac{\partial Ew}{\partial r} &= \frac{2r^3(r^2 + 2b\rho\sigma^2)}{(1 - \lambda)b(r^2 + b\rho\sigma^2)^2} > 0, \\ \frac{\partial CE_G}{\partial r} &= \frac{(1 - 2\lambda)r^3(r^2 + 2b\rho\sigma^2)}{(1 - \lambda)^2 b(r^2 + 2b\rho\sigma^2)^2}. \end{aligned}$$

According to $\partial Ew/\partial r > 0$, as r increases, economic outcome of enterprise will increase.

According to the sign of $\partial CE_G/\partial r$, conclusions can be drawn: when $\lambda \in (0, 1/2)$, it has $\partial CE_G/\partial r \geq 0$ which shows that income of government will increase as r increases. When $1/2 \leq \lambda < 1$, there is $\partial CE_G/\partial r < 0$ which shows that income of government will decrease as r increases.

For the conclusion (3) in the proposition, calculating first derivative for formula (9) and formula (10) concerning ρ respectively:

$$\frac{\partial Ew}{\partial \rho} = -\frac{r^4}{(1 - \lambda)b} \cdot \frac{b\sigma^2}{(r^2 + b\rho\sigma^2)^2} < 0, \quad \frac{\partial CE_G}{\partial \rho} = -\frac{r^4(1 - 2\lambda)}{2(1 - \lambda)^2 b} \cdot \frac{b\sigma^2}{(r^2 + b\rho\sigma^2)^2}$$

According to $\partial Ew/\partial \rho < 0$, It is known that risk aversion is enhancing, the economic returns of enterprise will decrease. When $\lambda \in (0, 1/2)$, $\partial CE_G/\partial \rho > 0$ which indicates that as ρ increases income of government will decrease. When $\lambda \in [1/2, 1)$, $\partial CE_G/\partial \rho > 0$ which shows that as ρ increases income of government will increase.

Proposition 2 shows that in the process of the government governing the environment and motivating enterprises, if the government pays more attention to ecological values and supports the upgrading of enterprises ($\lambda \rightarrow 1$), the economic income both government and enterprises will be increasing. When $\lambda \in (0, 1/2)$, revenue of government is positive while revenue of government itself will decrease and increasing income of enterprise will be greater than decreasing income of government. When $\lambda \in (1/2, 1)$, income of government is negative while increasing income of enterprise will be less than decreasing income of government. During the process of actual distribution, government will

adjust distribution coefficient β and fixed compensation α to adjust income of enterprise and result in income of government more reasonable. Therefore, when value preference of government prefers to mutual benefits, namely, the government focus on long-term interests with the bottom-line thinking, the revenue of both government and enterprises will increase to achieve win-win. When risk aversion of enterprise is enhanced and only short-term benefits are considered, the overall benefits will decrease as well as income of government.

4.2.3 Cost Analysis

Proposition 3. Given the model and other parameters are invariant, and the following conclusions may be drawn:

- (1) With the increasing of λ , the incentive costs and the general agency costs of enterprises due to information asymmetry will decrease. When $\lambda \in [0, b\rho\sigma^2/2(r^2 + b\rho\sigma^2))$, both incentive cost and the general agency cost are positive. When $\lambda \in (b\rho\sigma^2/2(r^2 + b\rho\sigma^2), 1/2)$, incentive cost is negative while general agency cost of enterprise is positive. When $\lambda \in (1/2, 1]$, both incentive cost and general agency cost of enterprise are negative.
- (2) When $\lambda \in (0, 1/2)$, general agency cost of enterprise caused by information asymmetry will increase with r increasing. When $\lambda \in (1/2, 1)$, general agency cost of enterprise caused by information asymmetry will decrease with r increasing. With increasing r , government will control general agency cost with choosing value preference parameter which is close to $1/2$.

Proof. The relation between government and the enterprise is actually principal-agent. For conclusion (1), when the information is symmetrical, the government can observe the effort level that enterprise protects the ecological environment, and then the incentive compatibility constraint IC is invalidated. The objective function of the government is as following:

$$\max_{\beta, e} u' = re - \frac{1}{2}(1 - \lambda)be^2 - \frac{1}{2}(1 - \lambda)\rho\beta^2\sigma^2 \tag{11}$$

Calculating first derivative for formula (11) concerning β and e respectively, the distribution coefficient and optimal effort level of the enterprise are as following:

$$\beta^{**} = 0, \quad e^{**} = r/(1 - \lambda)b.$$

$\beta^{**} = 0$ shows that government only provides fixed compensation to the enterprises when the information is symmetric. $e^{**} - e^* < 0$ shows that the effort level of enterprise that protect the environment will decrease when the information changes from symmetric to asymmetric. The net loss of economic income due to the decreasing in the effort level of enterprise is:

$$\Delta Ew = re^{**} - re^* = \rho r^2 \sigma^2 / (1 - \lambda)(r^2 + b\rho\sigma^2). \tag{12}$$

While corresponding cost savings of effort is as following:

$$\Delta C = \frac{be^{**2} - be^{*2}}{2} = \frac{(2r^2 + b\rho\sigma^2)\rho\sigma^2r^2}{2(1 - \lambda)^2(r^2 + b\rho\sigma^2)^2} \tag{13}$$

The incentive costs incurred by the government is:

$$\Delta IC = \Delta Ew - \Delta C = \frac{-2\lambda\rho\sigma^2r^4 + (1 - 2\lambda)br^2\rho^2\sigma^4}{2(1 - \lambda)^2(r^2 + b\rho\sigma^2)^2} \tag{14}$$

Meantime, the risk cost due to asymmetric information is

$$\Delta RC = \frac{\rho\sigma^2r^4}{2(1 - \lambda)^2(r^2 + b\rho\sigma^2)^2} \tag{15}$$

Add incentive cost to risk cost to get the general agency cost:

$$TC = \frac{(1 - 2\lambda)\rho r^2\sigma^2}{2(1 - \lambda)^2(r^2 + b\rho\sigma^2)} \tag{16}$$

Calculating first derivative for ΔIC and TC concerning λ respectively:

$$\frac{\partial \Delta IC}{\partial \lambda} = -\frac{(1 + \lambda)\rho\sigma^2r^4 + \lambda br^2\rho^2\sigma^4}{(1 - \lambda)^3(r^2 + b\rho\sigma^2)} < 0, \quad \frac{\partial TC}{\partial \lambda} = -\frac{\lambda\rho r^2\sigma^2}{(1 - \lambda)^3(r^2 + b\rho\sigma^2)} < 0$$

According to $\partial \Delta IC / \partial \lambda < 0$ and $\partial TC / \partial \lambda < 0$, incentive cost of enterprise and general agency cost due to the information asymmetry will decrease with λ increasing.

There is $\Delta IC > 0$ and $TC > 0$ in the condition of $\lambda \in [0, b\rho\sigma^2/2(r^2 + b\rho\sigma^2))$, namely, the incentive cost and general cost of the information due to changes from symmetric to asymmetric are both positive; there is $\Delta IC < 0$ and $TC > 0$ in the condition of $\lambda \in (b\rho\sigma^2/2(r^2 + b\rho\sigma^2), 1/2)$, which means incentive cost is negative and general agency cost is positive caused by the information changes from symmetric to asymmetric; there is $\Delta IC < 0, TC < 0$ in the condition of $\lambda \in (1/2, 1]$, in other words, both the incentive cost and the general cost of the information from symmetric to asymmetric are negative.

For the conclusion (2), $\partial TC / \partial r = (1 - 2\lambda)rb\rho^2\sigma^4 / (1 - \lambda)^2(r^2 + b\rho\sigma^2)^2 > 0$ in the condition of $0 < \lambda < 1/2$, which shows that when value preference parameter $\lambda \in (0, 1/2)$, TC will increase as r increases.

When $\lambda \in (1/2, 1)$, $\partial TC / \partial r = (1 - 2\lambda)rb\rho^2\sigma^4 / (1 - \lambda)^2(r^2 + b\rho\sigma^2)^2 < 0$, which shows that when value preference parameter $\lambda > 1/2$, TC will decrease as r increases. Because of monotonically decreases that $(1 - 2\lambda)/(1 - \lambda)^2$ in the condition of $\lambda \in (0, 1)$, concerning TC with r increasing, government will choose value preference parameter that is close to $1/2$ controlling general agency cost.

Proposition 3 shows that under state of uncertain information, government will prefer to ecological value. Based on development and ecological bottom-line thinking, government will adopt measures of incentives, encouraging enterprise invests in costs to promote technological reform and upgrading result in win-win, ecosystem and enterprise development can operate well. In order to sustain this economic operation mode for a long

term, government may decrease the pressure of information asymmetry, incentive cost, agency cost and increase economic output efficiency of enterprise. When marginal output of enterprise increases, government shall choose greater value preference parameter to control cost and achieve win-win cooperation.

5 Numerical Examples and Simulation

Assuming a local government G to encourage enterprise E to protect the ecological environment from the mode of traditional production to technological transformation and upgrading based on bottom-line of development and ecological. Assuming marginal output of the enterprise’s efforts is r and the ecological value preference parameter of government governance is λ . Assuming enterprise’s absolute risk aversion measure is ρ , the effort cost coefficient is b , and the standard deviation is σ . Assuming α, β, e are the fixed compensation, distribution coefficient and effort level of the enterprise respectively. Assuming w is income that enterprise engaged in ecological economic construction, CE_G is the government revenue, $\Delta IC, TC$ are the incentive cost and the general agency cost, respectively. And it is assumed that the retention utility of the enterprise is 0. Assumed numerical examples of each parameter and other specific numerical changes are shown in Table 1.

Table 1. Comparison of changes in government and enterprise parameters

r	λ	ρ	b	σ	α	β	e	w	CE_G	ΔIC	TC
2.00*	0.30	0.75	0.80	35.00	0.03	0.02	0.02	0.04	0.01	2.00	2.03
4.00*	0.30	0.75	0.80	35.00	0.42	0.05	0.15	0.61	0.16	7.56	7.99
6.00*	0.30	0.75	0.80	35.00	1.94	0.10	0.50	3.00	0.76	15.47	17.51
7.00*	0.30	0.75	0.80	35.00	3.42	0.13	0.78	5.47	1.34	19.78	23.44
8.00*	0.30	0.75	0.80	35.00	5.49	0.16	1.14	9.15	2.20	24.02	30.04
10.00	0.20*	0.75	0.80	45.00	6.30	0.10	1.19	11.88	4.40	47.28	54.14
10.00	0.30*	0.75	0.80	45.00	8.22	0.10	1.36	13.58	4.00	38.18	47.14
10.00	0.60*	0.75	0.80	45.00	25.19	0.15	2.38	23.76	- 4.99	- 99.63	- 72.18
10.00	0.70*	0.75	0.80	45.00	44.78	0.31	3.17	31.69	- 22.91	- 305.45	- 256.65
10.00	0.80*	0.75	0.80	45.00	100.75	0.38	4.75	47.53	- 71.28	- 975.99	- 866.21
6.00	0.25	0.50*	0.80	15.00	4.90	0.44	2.86	17.14	4.70	6.12	14.29
6.00	0.25	0.75*	0.80	15.00	4.88	0.33	2.11	12.63	3.59	9.14	15.79
6.00	0.25	1.00*	0.80	15.00	4.44	0.27	1.67	10.00	2.86	11.11	16.67
6.00	0.25	1.25*	0.80	15.00	4.00	0.22	1.38	8.28	2.46	12.49	17.24
6.00	0.25	1.50*	0.80	15.00	3.60	0.19	1.18	7.06	2.12	13.49	17.65

Note: *Indicates that the parameters are changed while other parameters are fixed.

From Table 1, the influence of change in value preference parameter λ , marginal output r and risk avoidance measurement ρ on incentive structure can be seen. As λ

increases, α , β , e , w will increase. When $1/2 \leq \lambda < 1$, $\Delta IC < 0$, $TC < 0$; When $0 < \lambda \leq 1/2$, $CE_G > 0$; when $1/2 < \lambda < 1$, $CE_G < 0$. As r increases, α , β , CE_G , w , etc. each value will increase. With the increase of enterprise risk avoidance measurement, enterprise partition coefficient will decrease and its profit will transform from performance distribution to fixed compensation.

6 Conclusions

Based on the view of two bottom-line thinking on development and ecology, in order to ensure the sustainable development and high-quality operation of the economy, the government and enterprises have changed the traditional environmental governance, supervision and punishment mechanism. Government administration and enterprises are new type of cooperation instead of the relationship between cat and mouse. The incentive contract model of government governance and enterprises is established based on the two bottom-line thinking of development and ecology. The traditional incentive contract model introduces ecological value preference parameters, and the model equilibrium changes due to the influence of ecological value preference parameters. After the equilibrium analysis of the model, the main conclusion reached is as follows: (1) Ecological value preference parameters can effectively coordinate the interest between government and enterprises. Governments with ecological value preferences can sacrifice part of their own interests at the cost of contract design to incentive enterprises to exert the best level of effort in ecological environmental protection based on development and ecological bottom-line thinking, and effectively control agency costs due to asymmetric information improve efficiency via ecological value preferences. (2) With the increase of marginal output, the government will change the incentive structure. Via modification of fixed compensation benefit and partition coefficient, government can stimulate enterprise to transform more fixed compensation benefit to incentive structure of distribution association with enterprise performance, and then raise the effort level of enterprise. To release the pressure of incentive cost increase, government will choose a mutual method to protect ecosystem from damage and promote the economic efficiency of enterprise. (3) With difference in risk avoidance extent of enterprise, change in risk preference may lead to change in incentive structure.

Under the framework of keeping the bottom-line of development and ecology, it should build environmental governance system that government-led and enterprises as the main body. Enterprises must perform their enterprise social responsibilities and establish the concept of Lucid waters and lush mountains are invaluable assets, keep to the basic national policy of saving resources and protecting the environment, and promoting comprehensive conservation and recycling of resource. Government should encourage enterprises to implement transformation, upgrading and green development, and give enterprises a series of incentive measures such as capital, tax exemption and policy preferences, in order to further stimulate the enthusiasm of enterprises. At the same time, the government should accelerate the establishment of a legal system and policy guidance for green production and consumption, build sound industrial system for the development of green and low-carbon cycle, and form a spatial pattern, industrial structure, and mode of production that can save resources and protect the environment.

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