



Research on Game Behavior of National Energy Security Risk Audit

Based on the Concept of Sustainable Development

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Abstract. The paper analyzes the behavioral characteristics of both parties in national auditing agencies and energy enterprises in safety risk auditing. Based on the basic assumption of rational economic factors, static game models and dynamic repeated game models are established, and the behavioral strategies of both parties in auditing under different conditions are obtained. This provides a reference basis for formulating scientific policy systems for national energy security risk auditing.

Keywords: Game behavior, Sustainable development, National energy security risk audit.

1 Introduction

Energy is the cornerstone of national economic development, and energy production security is an important foundation for national security. At present, although China's energy enterprises such as coal and oil have developed rapidly, energy consumption is usually high and the effective utilization rate of energy is low. The scarcity and non renewable nature of energy itself determine that the amount of energy will continue to decrease with the increase of development, which inevitably brings attention to energy security risks and sustainable development issues^[1]. In the past 10 years, China's domestic and external environment has undergone tremendous changes, and the downward pressure on the national economy continues to increase. The economic development model and policy orientation have also been adjusted in a timely manner in response to the impact of reality. From the new normal to high-quality development, supply side structural reform, domestic and international circular dual wheel drive to demand side reform, all have deeply demonstrated the important significance of economic policy formulation and implementation in resolving risks^[2] and achieving long-term sustainable development and other economic goals. National energy security guarantee is a prerequisite for risk prevention and control, maintaining national security, and high-quality development. From this perspective, national energy security risk audit has a certain historical inevitability^[3] and is the institutional cornerstone for achieving long-

term and controllable national energy security. As the supervisory agency for national economic activities, the national audit agency bears the heavy responsibility of energy sustainability supervision in the national energy security risk audit. It is not only necessary to review the compliance and use of relevant laws and regulations, energy policy measures, and energy management tools by the energy department, but also to adopt audit methods to continuously supervise and evaluate the safety, economy, scientificity, and utilization rate of energy enterprises in the process of energy production, operation, management and use^[4-5], form effective long-term supervision over the behavior control of energy enterprises, ensure that the national sustainable development strategy is truly implemented in the field of energy security.

2 Hypothetical Logic of Dual Subject Perspective in Game Theory

In the process of national energy security risk audit, the audit subject and the audited subject act as insiders in the game behavior. The audit subject is the national audit agency, and the audited subject is the energy enterprise. They all comply with the bounded rationality "economic person" assumption in economics, that is, they first consider pursuing their own interests, and then based on their different positions, rights, and obligations in risk audit activities, Each other will form a game to maximize their interests. This process conforms to the characteristics and requirements of game theory. Through game analysis, it is possible to better study their behavior and strategies, facilitate the development of audit governance action strategies based on the behavior strategies of each subject, and optimize the supporting policies and measures for national energy security risk auditing.

2.1 Rational Economic Man Theory

The rational economic man theory is a theory in the field of economics that assumes and abstracts the decision-making behavior of the subject. This theory suggests that economic entities consider the costs and benefits they face when making decisions, and choose options with benefits higher than costs to maximize their own interests and pursue utility maximization. Based on the assumption of rational economic man, both the audit subject and the audited subject will choose a more favorable strategy in the audit governance game. When the audit subject conducts audit supervision and inspection on the audited subject, for the audited subject, they have an information advantage in the relationship and can find omissions in the audit governance work. They conceal information through improper means, conceal facts through activities such as falsification and exaggeration, in order to seek personal gain.

For audit entities, there are two options in audit governance work: careful supervision and laziness. They will compare and analyze the benefits and efforts based on the energy, time, manpower and material resources invested in the actual audit situation, hoping to reap the maximum self benefit with the minimum effort. Therefore, they may

ignore the situations that arise in audit governance, and falsely report or exaggerate audit results in the audit results, to reduce the investment of national audit agency.

2.2 Analysis of the Behavior of Audit Parties in the Context of National Energy Security Risk Audit

In the audit governance game under the background of national energy security risk audit, the national audit agency, as the audit subject, will choose a strategy of "strict supervision" or "loose supervision" of the behavior of the audited subject with a certain probability. The "rational economic person" also applies to the national audit agency. Under the premise of considering one's own interests first, the choice of strategy mainly depends on the size of the workload and the difficulty of the work. In the absence of other incentives and punishment measures, national audit institutions may appear to be perfunctory in their audit work. Considering the independence and effectiveness of the operation of the national audit system, the situation of collusion between audit agencies and energy enterprises will no longer be explored.

As the audited entity, energy enterprises will choose to exploit institutional loopholes and seek their own interests in audit governance. Their main strategies are "sustainable development" and "extensive management". When there are no other mechanisms to incentivize or when the national audit agencies have inadequate supervision, energy companies are more inclined to adopt a strategy of "extensive management", disregarding the requirements of national energy security management, and are willing to take huge risks to seek huge improper benefits.

Therefore, in the national energy security risk audit game, the pure strategic choice of the national audit agency is to conduct "strict supervision" or "loose supervision", while the pure strategic choice of energy enterprises is "sustainable development" or "extensive management".

3 Construction of a Game Model for National Energy Security Risk Audit

3.1 Game Model Assumptions

Assumption 1: In the audit governance game under the background of national energy security risk audit, the stakeholders are the national audit agency and energy enterprises, respectively. When conducting game analysis, national audit institutions are in a dominant position, while energy enterprises are in a subordinate position, and should cooperate with the implementation of audit work.

Assumption 2: The national audit agency and energy enterprises are both rational economic individuals in the game process, and both parties pursue the maximization of their respective interests and formulate action strategies to obtain maximum returns with the least effort.

Assumption 3: The audit entity has two strategies, namely "loose supervision" or "strict supervision", and the audited entity can choose two strategies: "sustainable development" or "extensive management".

Assumption 4: The audit subject and the audited subject act simultaneously during the game, and are fully aware of each other's strategy choices and payment value information under corresponding strategies. If the game is played more than once, the game can be repeated multiple times. Therefore, this game is a repeated game under complete information.

Assumption 5: The meanings of various mechanism parameters in the game process are as follows.

x_t : The probability of the national audit agency choosing "strict supervision" in the t -th game;

y_t : The probability of the national audit agency choosing "strict supervision" in the t -th game;

c_{11} : The cost that energy enterprises need to pay for adopting "sustainable development";

c_{21} : When energy enterprises adopt "extensive management", the punishment imposed on energy enterprises by the national audit agency under "strict supervision" conditions;

c_{12} : Penalties imposed on energy enterprises under strict supervision by national auditing agencies when they adopt "extensive management";

c_{22} : The cost that national audit agency need to pay for choosing "loose supervision";

m_t : In the t -th game, when energy enterprises choose "extensive management", the national audit agency adopts a "loose supervision" strategy for audit governance, and there is $m_t \in [0, 1]$.

c_{13} : When energy enterprises adopt the "extensive management" strategy, the national audit agency adopt the "loose supervision" strategy, resulting in losses to the country caused by problems with energy enterprises in audit governance.

c_{23} : When the national audit agency adopts the "loose supervision" strategy, the "extensive management" strategy adopted by energy enterprises results in insufficient audit governance and losses to national energy security management.

q_{11} : Benefits obtained by energy enterprises when adopting a "sustainable development" strategy;

q_{21} : When the national audit agency adopts a "strict supervision" strategy, the energy enterprise adopts a "sustainable development" strategy to bring benefits to the enterprise.

δ : The discount factor for the conversion of benefits in repeated games of the energy enterprise, $\delta \in (0, 1)$.

T : The total number of games between the energy enterprise and the national audit agency, and $t \leq T$.

3.2 Static model establishment

This section will construct the first game model in the repeated game between energy enterprises and national audit institutions - static game. In this game, the strategic choice of the national audit agency is to conduct "strict supervision" or "loose supervision", while the strategic choice of energy enterprises is "extensive management" or "sustainable development". By constructing a static game payment matrix between the national audit agency and energy enterprises, it helps to analyze how the behavioral strategies of both parties under this model affect each other in the future. At the same time, as a basis for balancing strategies, this model is used multiple times to analyze the strategy selection behavior of both parties in repeated games, providing scientific countermeasures for promoting national audit institutions to better and continuously supervise the safety management of energy enterprises and continuously and effectively carry out audit governance^[6]. The payment matrix of the game between national audit institutions and energy enterprises is shown in Tab 1.

Table 1. Static Game Matrix between National Audit Institutions and Energy Enterprises

		energy enterprises	
		extensive management ($1 - y_1$)	sustainable development (y_1)
national audit agency	loose supervision ($1 - x_1$)	$-c_{13}m_1, -c_{23}m_1 - c_{22}$	$q_{11} - c_{11}, q_{21} - c_{22}$
	strict supervision (x_1)	$-c_{12}, c_{12} - c_{21}$	$q_{11} - c_{11}, q_{21} - c_{21}$

3.3 Analysis of static game model

According to the payment matrix, the expected benefits W_1 and W_2 for energy enterprises to choose the "sustainable development" strategy and the "extensive management" strategy are calculated as follows:

$$W_1 = x_1 (q_{11} - c_{11}) + (1 - x_1)(q_{11} - c_{11}) = q_{11} - c_{11} \quad (1)$$

$$W_2 = -c_{12} x_1 + (1 - x_1)m_1 (-c_{13}) = m_1 (-c_{13}) - x_1 m_1 (-c_{13}) - x_1 c_{12} \quad (2)$$

The average expected benefits $\overline{W}$ of energy enterprises are:

$$\overline{W} = y_1 * W_1 + (1 - y_1) * W_2 \quad (3)$$

Similarly, the expected benefits (W_1 , W_2) of the “strict supervision” and “loose supervision” strategies of the national audit agency, and the average expected benefits ($\overline{W}$) of the national audit agency are calculated as follows:

$$\begin{cases} W_1 = y_1(q_{21} - c_{21}) + (1 - y_1)(c_{12} - c_{21}) = y_1(q_{21} - c_{12}) + c_{12} - c_{21} \\ W_2 = y_1(q_{21} - c_{22}) + (1 - y_1)(-c_{23} * m_1 - c_{22}) \\ \overline{W} = x_1 * W_1 + (1 - x_1) * W_2 \end{cases} \quad (4)$$

Calculate the partial derivatives of x_1 and y_1 for the average expected benefits functions of energy enterprises and national audit agency, which are equal to 0, to obtain the optimal benefits of the mixed strategy of energy enterprises and national audit agency, and (x_1^*, y_1^*) is:

$$\begin{cases} x_1^* = [m_1(-c_{13}) - (q_{11} - c_{11})] / [m_1(-c_{13}) + c_{12}] \\ y_1^* = [c_{23}m_1 + c_{12} - (c_{21} - c_{22})] / (c_{23}m_1 + c_{12}) \end{cases} \quad (5)$$

This indicates that the static game model has a unique Nash equilibrium point (x_1^*, y_1^*) , and the mixed equilibrium strategies of national audit agency and energy enterprises respectively are $(x_1^*, 1 - x_1^*)$ and $(y_1^*, 1 - y_1^*)$. Next, analyze the factors affecting the Nash equilibrium point, through the “rational economic man” theory, analyze what audit governance measures can be taken to achieve the optimal Nash equilibrium point (strict supervision, sustainable development).

Part 1: By analyzing x_1^* , it can be concluded that the main factors that affect the probability of national audit agency adopting strict supervision strategies are: ①The benefits of energy enterprises adopting sustainable development strategies: $(q_{11} - c_{11})$; ②Income of energy enterprises under extensive management and loose supervision by national audit agency $(-c_{13})$; ③Penalties for energy enterprises under strict supervision by national auditing agency when adopting extensive management: c_{12} ;

Calculate the partial derivative of x_1^* over $(q_{11} - c_{11})$ and c_{12} , there is:

$$\frac{\partial x_1^*}{\partial c_{12}} < 0, \frac{\partial x_1^*}{\partial (q_{11} - c_{11})} < 0 \quad (6)$$

From the above equation, it can be seen that the probability of national audit agency adopting "strict supervision" strategies is negatively correlated with the penalties suffered by energy enterprises and the net benefits obtained by energy enterprises. When there is insufficient punishment for energy enterprises in audit governance, the national audit agency will strengthen supervision of energy enterprises and promptly urge them to rectify; The smaller the sustainable development net benefits obtained by energy enterprises, the greater the recurrence possibility of problems. The national audit agency will also increase their strict supervision and urge them to implement effective management in the long term, minimizing the occurrence of safety problems caused by extensive business management.

Part 2: By analyzing V, it can be concluded that the main factors that affect the probability of national audit institutions adopting sustainable development strategies are as follows:

① The cost difference between strict supervision strategy and passive supervision strategy adopted by national audit institutions: Q;

② Under the strategy combination of "extensive management and strict supervision" in a static game, the additional losses paid by the national audit agency in audit governance: W;

③ The punishment for energy enterprises under the "extensive management" strategy adopted by energy enterprises and the "strict supervision" strategy implemented by national audit agencies: E;

A takes the partial derivative of B to analyze the relationship between them, and obtains:

$$\frac{\partial y_1^*}{\partial c_{12}} > 0, \frac{\partial y_1^*}{\partial (c_{21} - c_{22})} < 0 \quad (7)$$

From the above conclusion, it can be concluded that the probability of energy enterprises choosing sustainable development strategies is negatively correlated with the cost difference between the "strict supervision" strategy and the "loose supervision" strategy chosen by national audit institutions, and is positively correlated with the punishment they suffer.

This indicates that in order to increase the probability of energy enterprises choosing "sustainable development" in audit governance, measures can be taken at the level of national audit institutions: firstly, scientific measures can be taken to reduce the cost of "strict supervision" by national audit institutions, such as allocating audit resources reasonably and reducing the work pressure of auditors. The second is to increase the cost of implementing "loose supervision" by national audit institutions, such as formulating corresponding punishment plans that should be adopted when discovering their "extensive management"; At the level of energy enterprises, measures can be taken to increase the punishment for extensive management in energy enterprises, in order to reduce the

probability of choosing the "extensive management" strategy in a way that reduces expected returns.

3.4 Analysis of Repetitive Game Model

In the game between national audit institutions and energy enterprises, the participants are all bounded rationality, which means that the game between national audit institutions and energy enterprises is long-term and repetitive, and it is often impossible to find the optimal strategy from the beginning. Therefore, it is necessary for national audit institutions and energy enterprises to constantly engage in games and adjust their behavior choices to obtain the best strategy.

In the process of static game model analysis, the focus is on how to formulate measures to affect the Nash equilibrium point of both parties, ensuring that the behavior of national audit institutions and energy enterprises converges, and jointly achieving the maximization of audit governance benefits. This section will analyze the repeated game between energy enterprises and national audit institutions in the audit governance process under the static game payment matrix model, and analyze the strategy selection behavior of both parties in the subsequent repeated game, in order to promote better and continuous supervision and promotion of energy enterprise audit rectification by national audit institutions, and provide effective decision-making suggestions.

In the first static game process, we can learn that the optimal strategy for the national energy security risk audit process is (strict supervision, sustainable development), and analyze the influencing factors and how to formulate measures for the equilibrium point. However, in repeated games, the strategic tendencies of both parties may change. Therefore, the repeated game analysis here provides the following game conditions:

Assuming that at the beginning of the first round of the game, the national audit agency maintains a trust attitude towards energy enterprises and adopts a loose supervision strategy. If the energy enterprise chooses a sustainable development strategy, then in the next repeated game, the national audit agency will still choose the same strategy, and both parties will consciously and steadily promote audit governance work; If energy enterprises adopt a "extensive management" strategy, the national audit agency's strategic choice will always adopt "strict supervision" measures from the next start to the end of the game.

Therefore, according to the strategy selection situation of energy enterprises in the next game, and combined with the corresponding benefits in the payment matrix of the first game model. It can be seen that in two situations, the benefits A obtained from sustainable development and B obtained from extensive management of energy enterprises in multiple repeated game processes are:

$$\begin{cases} W_{m1}^1 = (q_{11} - c_{11})(1 + \delta + \delta^2 + \dots + \delta^{T-1}) = (q_{11} - c_{11})(1 - \delta)^{T-1} \\ W_{m2}^1 = -m_i c_{13} + (q_{11} - c_{11})(\delta + \delta^2 + \dots + \delta^{T-1}) = m_i q_{13} + \delta(1 - \delta)^{T-2}(q_{11} - c_{11}) \end{cases} \quad (8)$$

Through the analysis of the previous model, if $W_{m1}^1 - W_{m2}^1 \geq 0$, then δ needs to satisfy the relationship:

$$\delta \leq [q_{11} - c_{11} - m_t(-c_{13})] / [2(q_{11} - c_{11})] \quad (9)$$

If $\delta^* = [q_{11} - c_{11} + c_{13}m_t] / [2(q_{11} - c_{11})]$ is recorded, then when $\delta \leq \delta^*$, as long as the energy enterprise does not implement the "extensive management" strategy, the national audit agency will not implement the "strict supervision" strategy for the audit governance work of the energy enterprise. If the national audit agency discovers that energy enterprises have adopted extensive management strategies during the repeated game process, they can immediately implement a permanent "strict supervision" strategy based on the above game conditions until the game ends. Energy enterprises will continue to accept punishment from national audit institutions in subsequent audit governance, in order to reach the equilibrium point of national energy security risk audit, so that both parties can achieve the best strategy under the constraints of game conditions, effectively improve the work standards and management quality of both parties, and avoid the recurrence of similar problems in audit governance. At the same time, according to this formula, it can also be concluded that the better the audit governance situation, the easier it is to promote the achievement of a balanced strategy (strict supervision, sustainable development) between national audit institutions and energy enterprises, which is in line with the actual situation of national energy security risk auditing.

4 Summary of Game Strategies for National Energy Security Risk Audit

4.1 Continuously improving the effectiveness of energy security risk audit governance through "supervision and improvement"

According to static game analysis, in order to achieve effective audit governance, national audit institutions and energy enterprises need to implement strategies of "strict supervision" and "sustainable development" respectively. In the repeated game, it is also demonstrated in what situation the national audit institution will adopt permanent strict supervision.

Based on the above discussion, it is essential to make improvements to the current situation of high workload and lack of resources for auditors in order for national audit institutions to adopt strict supervision measures and achieve maximum efficiency in national energy security risk auditing. National audit institutions should reasonably allocate audit resources, enhance the safety risk management awareness of energy enterprises, make them treat risk auditing correctly, reduce the human, material, and financial costs required for actual auditing, and ensure that the deterrence of auditing can be maintained in the long term. At the same time, it is possible to increase the supervision and assessment mechanism for national audit institutions, incorporate the authenticity and effectiveness of audit work into the year-end evaluation work, and encourage national audit institutions to truly take supervisory measures and continuously improve the level of audit governance work. For energy enterprises, it is necessary to improve their existing work and operation mechanisms, transform the local enterprise interest

orientation into a global national energy security career orientation, and avoid situations where the interests of enterprises are harmed by extensive management, even at the expense of harming the overall interests of the country.

4.2 Effectively increasing the enthusiasm for long-term audit construction through the combination of rewards and punishments

According to game analysis, increasing punishment intensity can increase the probability of reaching the optimal equilibrium point for both energy enterprises and national audit institutions. Therefore, it can be considered to use assessment and evaluation to establish standards for implementing rewards and punishments, implement both rewards and punishments, enhance the enthusiasm and initiative of both parties in energy security risk auditing, and improve the effectiveness of audit governance.

For the assessment and evaluation of energy enterprises, the national audit agency can formulate safety management and implementation assessment standards for energy enterprises, and after collecting opinions, issue them to energy enterprises for compliance and implementation. According to the assessment standards, energy enterprises select four levels of excellent, good, medium, and poor work for relevant leaders, which are included in year-end merit evaluations and daily commendations, and are publicly announced to achieve full supervision. By prolonging the impact of assessment conclusions on energy enterprises, we guide them to pay more attention to the long-term maintenance of audit governance, enhance their enthusiasm for "sustainable development" and gain profits, and encourage them to take proactive measures to achieve the optimal audit governance strategy.

4.3 Using the "win-win concept" to scientifically establish mutual linkage and achieve long-term effectiveness

During the audit process, the national audit agency and energy enterprises will engage in a game based on the interests and needs of both parties, and adopt the most advantageous strategy for themselves. However, the highest level of the game is the consistency of target interests. At the same time, in the context of the concept of sustainable development, the ultimate goal of national audit institutions and energy enterprises is to promote the formation of a high-quality energy market for economic development, resolve potential energy security risks and energy supply crises, and ensure the sustainable development of the national economy and society. Therefore, in the audit governance work, only through good cooperation between energy enterprises and national audit institutions, and scientific linkage between both parties, can the work of both parties be more harmonious, outstanding, efficient, and achieve long-term effectiveness of audit governance.

Therefore, both national audit institutions and energy enterprises need to have a mutually beneficial and win-win work philosophy, each exerting their maximum efficiency in audit governance work, while assisting each other in improving work efficiency, promoting the long-term maintenance of audit governance, and continuously forming a high-pressure situation for energy safety risk control.

5 Conclusion

The energy industry is the pillar industry of China's industrial development, which is related to the country's economic lifeline and affects the sustainable development of the national economy and society. The national energy security risk audit plays an irreplaceable role in strengthening energy strategic management and timely resolving energy risk crises. Starting from the perspective of auditing, this paper analyzes the behavioral characteristics of both national auditing agencies and energy enterprises in safety risk auditing. Based on the basic assumption of rational economy, static game models and dynamic repeated game models are established, and the behavioral strategies of auditing parties under different conditions are obtained. This provides a reference basis for formulating scientific policy systems for national energy security risk auditing. From the game results, it is necessary to establish a long-term mechanism for national energy security risk audit to guide and regulate the behavior of both parties towards a common security strategy goal and achieve dynamic equilibrium, ensuring the stability of national energy strategy security.

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