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Contractual Mechanisms in National Park Management: A Multi-Task Principal–Agent Model

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Abstract: In the management of national parks, the principal–agent relationship is key to efficient and effective management. Based on multi-task principal–agent theory, this study examines the dual functions of central government incentives and guidance and the objectives of local National Park Administration offices in environmental conservation and reasonable resource utilization. First, this study constructs a multi-task principal–agent model for central and local governments within the national park management system and identifies effective contractual mechanisms. Second, this study examines the relationship between the intensity of central government incentives and the ecological conservation atmosphere coefficient. Third, by integrating the three stages of national park management system advancement, this study explores the central government's incentive strategies at different stages. The findings indicate that local governments receive limited ecological conservation support, underscoring the need for long-term central government incentives. The findings also confirm that the effective management of national parks by local governments can only be achieved by eliminating external uncertainties, reducing the variable costs of innovative advancements, and controlling risk aversion in local National Park Administration processes. In addition, this study includes empirical data for sensitivity analyses to understand the robustness of the model under different scenarios. This study offers valuable insights and practical suggestions for enhancing national park management.

Keywords: national parks; multi-task principal–agent model; central and local governments; management contract; incentive strategies

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1. Introduction

China's rapid economic development has led to a series of environmental issues, including pollution, water scarcity, ecosystem degradation, and loss of biodiversity. In response, China has implemented various ecological and environmental protection policies and developed a national park system with distinctive Chinese characteristics. National parks are an essential component of ecological civilization construction and are a key focus of China's ecological environment governance reforms. National parks are typically established and managed by a country's central government and reflect the broader national intent. China is no exception. First proposed at the Third Plenum of the 18th Central Committee of the Chinese Communist Party in 2013, pilot national park systems were instituted in 2015, and the first batch of national parks was officially established in 2021. Continuing with the issuance of the "National Park Layout Plan" in 2022, China's national park construction has progressively developed over a decade, alongside the comprehensive deepening of reforms. This has resulted in a national park system that aligns with China's national conditions and embodies the concept of ecological civilization. Considered a key component of advancing ecological civilization, the construction of a nature reserve system centered on national parks was a significant agenda item at the 19th National Congress of the Chinese Communist Party [1]. National parks play a critical role in environmental protection, maintaining ecological balance, preserving biodiversity, and safeguarding precious natural and cultural heritage [2]. Typically founded to protect and conserve unique and irreplaceable natural environments, national parks possess multiple important functions [3]. Globally, the national park movement has shifted from unilateral participation to dominant and multi-stakeholder involvement and from passive implementation to active conservation [4]. To address the challenges posed by various environmental issues, the central and local governments play complementary roles in the management of national parks. The central government is primarily responsible for policy formulation and financial support, while local governments are tasked with implementing these policies and managing daily operations. This approach leverages the central government's macro-regulatory capabilities and the local governments' autonomy in policy execution. However, the model in which the central government delegates national park management to local governments requires a high level of coordination and effective policy implementation.

China's national parks are managed via a hierarchical system led by the central government and implemented by the National Forestry and Grassland Administration, also known as the National Park Administration, which performs national management functions. Figure 1 illustrates the chain management system of national parks in China. Theoretically, when local governments implement the decisions of the central government, which include relevant regulations, policies, and standards, they must adhere to the conformity and standardization required by these policies. This ensures that both central and local governments align with the primary goal of ecological protection in national park pilot projects. However, in practice, local governments have independent and distinct policy utility functions from the central government. When implementing policies, they need to consider community interests and participation, balancing ecological protection and resource utilization through flexible management policies and discretional responsibilities [5]. Consequently, there is a high likelihood that local governments will develop region-specific policies. This can lead to flexible interpretations and adaptations of higher-level government policies during the construction and management of national parks.

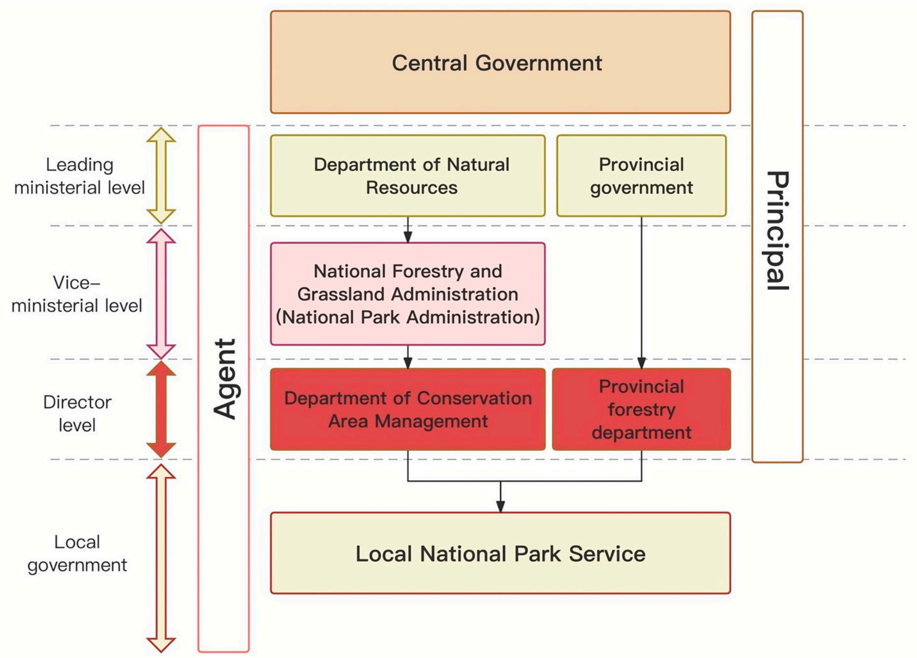


Figure 1. Chain management system of national parks in China.

Balancing ecological protection and the rational use of resources is the scientific positioning of national parks and the original intention behind their establishment. However, the conflict between ecological protection and resource utilization has a long-standing history [6,7]. Addressing the long-standing institutional inertia of prioritizing resource utilization over protection and establishing a national park management system that prioritizes protection while balancing resource utilization is a crucial mission in the construction of an ecological civilization in the new era. Currently, under the unified leadership of the National Park Administration, three management models for national parks have emerged: direct central management, dual leadership by the National Park Administration and local governments, and vertical management by local governments. These models differ in their integration of central and local governance, but all of them involve communication between central and local government levels. The central government adopts a macro-departmental approach, delegating administrative responsibilities to the National Forestry and Grassland Administration (National Park Administration); thus, they can be treated as a single principal. Since national parks are subject to administrative regional divisions, local National Park Administration processes rely on the various functions and authorities of local governments for management, making them complementary. Consequently, a typical principal–agent relationship exists between the central and local governments, simplifying and clarifying the sharing of responsibilities and enhancing policy implementation effectiveness, with the central government as the principal and local National Park Administration processes as agents.

Local National Park Administration processes possess an informational advantage relative to the central government, and their objectives are not entirely aligned. Ecological protection and resource utilization hold different weights in their respective utility functions. The central government prioritizes ecological protection, which holds a dominant position in its utility function, whereas local governments view ecological protection as only part of their utility function. Due to inertia or local interests, resource development and utilization also hold significant weight. Local governments have a certain degree of discretionary power and may selectively implement policies issued by the central government based on their own objectives. For example, compared to resource development, the outcomes of ecological protection are difficult to measure directly and do not yield immediate results, whereas resource development is a more familiar process. Local governments may exploit policy loopholes to meet their resource development objectives. Additionally, the central government incentivizes local governments to engage in ecological protection and resource utilization through subsidy policies. These subsidies are typically determined based on factors such as the area of the national park, population density, and the results of initial pilot projects. Due to regional differences, the financial subsidy policies for national parks also vary. However, the subsidy mechanism based on the aforementioned objective factors may not fully incentivize local governments, as it often lacks consideration of their actual efforts and ecological protection outcomes [8]. The absence of performance-based subsidies results in insufficient motivation for local governments to effectively fulfill their ecological protection tasks in national parks, leading to a decline in work efficiency.

In addition to their primary function of protecting the authenticity and integrity of important natural ecosystems, national parks fulfill various other comprehensive functions, including research, education, and recreation [9]. For ease of analysis, this study summarizes these four functions into two domains: ecological environment protection and reasonable utilization (i.e., restricted use). By reflecting the scientific positioning and original intent underpinning national parks, local National Park Administration processes have the dual role of ensuring ecological protection and the reasonable utilization of resources within the parks [10]. However, the conflict between ecological protection and rational utilization has a long-standing history. The central government needs to utilize fiscal subsidies and policy regulations as tools for adjustment and constraint, implementing diversified economic and political incentives to ensure that local governments balance their efforts between these two tasks. This approach aims to reverse the long-standing institutional inertia of prioritizing resource utilization over protection, ultimately establishing a national park management system that prioritizes protection while balancing it with utilization.

This paper details the construction of a multi-task principal–agent model considering the dual roles of the central government in incentivizing and guidance, as well as the dual tasks of the local National Park Administration processes in ecological environment protection and rational resource utilization, to establish an effective contractual mechanism. It also examines the relationship between the central government's incentive intensity and the coefficient of the ecological protection atmosphere, identifying the influencing factors of incentive intensity, the ecological protection atmosphere coefficient, and local government effort levels. By analyzing the three stages of the national park management system's development, this study explores the central government's incentive strategies at different stages. Next, empirical data are used to validate the reliability of the theoretical model, and a sensitivity analysis is conducted to understand the model's stability and robustness under different scenarios. Finally, a discussion of the relationship between national park incentive policies and ecological protection outcomes provides targeted strategies and recommendations for the policy coordination between central and local governments.

2. Literature Review

2.1. National Park Management System

The academic community has reached the following three consensuses regarding China's national parks. The construction concept emphasizes "ecological protection first, national representativeness, and public welfare for all", with ecological protection being paramount, signifying nationwide importance and serving the public interest. This concept highlights preserving the original and complete state of nationally significant natural ecosystems and endows national parks with functions such as scientific research, education, and recreation. National parks are a crucial component of China's nature reserve system, playing a key role in protecting biodiversity, maintaining ecological balance, and promoting sustainable development. In advancing the construction of national parks, the central government should strive to optimize and update the country's nature reserve system and related institutions. The core goal of establishing the national park system is to create a unified, standardized, and efficient management system [4,11].

During the construction of the national park system, scholars have proposed various suggestions for improvement. Huang Xisheng and Guo Tian argued that the public-welfare-enhancing nature of national parks should be strengthened through public interest legislation [12]. He Siyuan et al. suggested forming multi-functional zoning management by coordinating land use [13]. Rong Yu and Zhuang Youbo proposed that a broader human–land relationship adjustment strategy should be adopted to address resettlement issues [14]. Ding Zi et al. emphasized the need to further clarify the responsibilities of governments at all levels and enhance governance capacity [15]. Yan Guotai and Song Lin recommended drawing on World Heritage assessment methods to expand value evaluation in the landscape dimension, achieving a win–win situation for resource protection and regional development [16]. Matos Amemarlita et al. stated that management should reach an agreement between communities and conservation institutions to ensure ecological, livelihood, and spiritual functions [17]. Esaie Waya et al. advocated for local residents to participate in sustainable management [18]. Ikrame Selkani pointed out that management is a tool for planning protected areas and needs to be combined with land management goals [19]. Geng Dehui Christina et al. studied the impact of seasonal variations in terms of tourist satisfaction on the sustainable management of national parks [20]. Melina Barrio et al. used latent class models to analyze preferences for the management plan of Spain's Atlantic Islands National Park [21]. Negru Ciprian et al. developed a grassroots management effectiveness assessment for Ecuador's national parks [22]. Heiland Stefan et al. summarized the experiences of evaluating the management effectiveness of German national parks, emphasizing the importance of establishing quality systems [23]. The academic community has extensively discussed how to optimize the relationship between central and local governments in managing national parks and generally agrees that their functions differ. Therefore, the two should form a complementary and interactive relationship in financial, administrative, policy, and legislative areas [24]. Specifically, an effective statutory cooperation framework between the central and local governments should be established based on national park legislation, clearly defining the responsibilities of each level of government and aligning their regulatory goals through unified performance evaluation. Additionally, the financial management system should emphasize the economic principle of unifying financial and administrative powers [25,26]. This transformation would shift the relationship between central and local governments in national park policy implementation from one of "interest-based competition" to "interest-based cooperation".

2.2. Principal–Agent Theory

This study examines the principal–agent relationship in national park management in the Chinese context. Principal–agent theory, also known as incentive theory or information economics, focuses on contract design under information asymmetry assuming complete contracts. In contrast, contract theory focuses on contract design under incomplete contracts. First proposed by Holstrom and Milgrom, the multi-task principal–agent model originates from the single-task principal–agent model [27]. According to the multi-task principal–agent model, as the agent undertakes multiple tasks and the principal cannot observe the agent's efforts, the principal designs contracts to incentivize the agent to optimally allocate efforts across multiple tasks to achieve the principal's goals [28]. Compared to the single-task principal–agent model, the multi-task model achieves a balance between risk and incentive in single tasks by sharing risks to motivate the agent's effort, and it guides the allocation of the agent's efforts. By building on this idea, subsequent studies have used and expanded this model to examine the nature of tasks (complementary or substitutive), the measurability of output (performance), and game dynamics [29–31]. The multi-task principal–agent model is widely applicable and has been employed to examine multi-task principal–agent issues in China's public sector [32–34] and analyze multi-task agency issues under the general government–enterprise relationship [35–37].

When the number of principals in a single-task principal–agent model expands from one to multiple, the bilateral agency extends to multi-lateral or common agency. Developed by Bernheim and Whinston, the model of common agency contends that agents can cooperate or compete with one another; the degree of effort by agents affects the principals' profits, and the principals may try to influence the agents accordingly. Regardless of whether the principals collude, the overall incentive scheme will be effective and lead to efficient outputs [38,39]. Subsequent studies have expanded on the theory to investigate information completeness or incompleteness, the homogeneity or heterogeneity of the multiple tasks, whether the game dynamics are static or dynamic, and whether principal strategies are cooperative or competitive [40–43]. In the Chinese context, scholars have used the theory of common agency to analyze the incentive issues among Chinese state-owned enterprise managers [44,45], the public goods provision mechanism of local governments [46], the incentive equilibrium under primary and secondary principal–agent relationships in state-owned enterprises [47], and the regulatory strategies of public hospitals under a multi-principal multi-task framework [48].

Meanwhile, the bulk of current research on contracts and incentives adopts the government–enterprise perspective. According to Etro, managers of external tacit productivity (e.g., governments) in the R&D process need to set appropriate incentive contracts to mitigate the risks of corporate technological innovation and maximize corporate interests [49]. Introducing principal–agent theory into government regulatory decisions has helped optimize the government's incentive capabilities and effects [50], enabling the government to continue ensuring the supply of various resources in the event of market mechanism failure [51]. Acemoglu et al. confirmed that regulatory measures represented by environmental taxes and incentive strategies primarily comprising R&D subsidies are two core drivers of corporate innovation, but the usage interval of tax regulations is narrower. Therefore, optimizing incentive contracts is key to forming a green innovation pattern [52]. Given the dual economic characteristics of China and the "promotion tournament" characterizing local governments, enterprises frequently engage in the deceitful stimulation of incentives, leading to the breakdown of government–enterprise incentive contracts [53]. Under conditions of information asymmetry and risk aversion differences, local governments are more inclined to collude with enterprises, raising concerns for the central government regarding the delegation of power and generating delegation costs [54,55]. Although the active performance of local governments has facilitated the flexible transformation of the market economy and created a favorable innovation atmosphere, issues such as benchmark competition, the pursuit of financial resources, and soft budget constraints have forced local governments to constantly adjust their risk preferences to maximize their own benefits [56,57]. In the game between the central and local governments, local governments' decision making is paramount, regardless of whether it involves prioritizing upper-level requirements or overdrawing local potential through the "public pool" to meet "promotion" needs, which are then adjusted by successors. At the same time, the driving force affecting local government behavior lies in the central government [58,59]. In the management process, the central government is responsible for the delegation of duties and authority, and local governments face the possibility of moral hazards and ex post settlements [60]. Therefore, in the management of national parks, greater attention should be paid to the principal–agent relationship formed between central and local governments.

2.3. Comparative Study of National Parks in Developed Countries

The policy conformity, local government autonomy, and reasonable exercise of discretionary responsibilities demonstrated by developed countries in their national park systems provide valuable references and lessons for the development of national parks in China.

The management model of national parks in Germany grants significant autonomy to local authorities. The federal government provides macro-level guidance, while state governments are responsible for the specific operations of national parks. Under this framework, where the federal government sets the structure and state governments manage autonomously, several common issues between German and Chinese national parks have been identified. One prominent issue is the inconformity in management standards across state national parks [61]. Since the costs of conservation management are primarily borne by state governments, experts in some conservation fields have pointed out that current funding is insufficient [62]. To address these issues, the German federal government has established unified general regulations and standards for national park management. Additionally, federal subsidies have been designated as the primary source of funding for national parks, thereby promoting the standardization and normalization of national park management practices.

In the management policies of the National Park Service (NPS) in the United States, the central government's core role in policy and standard formulation is significantly emphasized [63]. Local governments must strictly adhere to existing laws, regulations, and executive orders when implementing relevant policies, ensuring conformity and stability in policy execution. This approach aims to preserve the integrity and sustainability of national park resources so they can be passed on to future generations intact. Comparative studies have revealed that the NPS places great importance on the planning of national parks. From the macro level of the "National Park System Plan" to the micro level of "specific construction activities within each national park unit", as well as in the improvement of the funding guarantee system, the NPS has established a mature and comprehensive planning system. This system provides a robust institutional framework for the protection, management, and sustainable development of national parks.

The authorization and management of national parks in the United Kingdom exhibit a distinct "top-down" characteristic. Each national park has a dedicated National Park Authority, whose members are composed of representatives from both national and local governments. National representatives make up one-third to one-quarter of the membership. In terms of funding, UK national parks primarily rely on national government grants, supplemented by some local government funding. This organizational structure ensures that management personnel maintain close communication and cooperation with the central government, thereby securing sufficient funding and external resources. This effective coordination facilitates the advancement of foundational surveys, specialized research, and daily management tasks within the parks [64].

The reform of the French national park system, achieved by properly managing the relationships between different levels of government and optimizing governance structures, successfully created the Parcs Nationaux de France (PNF) alliance, which draws on the regional park management model. This initiative not only established a framework that effectively balances various interests but also promoted the formation of a green development mechanism, making this balance both intrinsic and sustainable. In the management practices of French national parks, the charter serves as the foundational element of the system. Its development process involves extensive input from multiple stakeholders and thorough deliberation to ensure its feasibility and effectiveness at the operational level. As a result, the implementation of the charter avoids the dilemma of "countermeasures at the lower levels", ensuring the consistency and stability of management policies [65].

Policy conformity is a crucial cornerstone for the stable long-term development of national parks. In advancing the formulation of national park policies in China, it is essential to ensure that policies at all levels are well-coordinated and interconnected, forming a comprehensive, scientific, and standardized policy system that avoids conflicts and contradictions between policies. Local government autonomy plays an irreplaceable role in the development of national parks. Drawing on the advanced experiences of developed countries, China should fully respect the principal status and innovative spirit of local governments. Local governments should be encouraged to creatively engage in the construction and management of national parks, aligning with national policy directions while considering local realities to develop distinctive management models. Discretionary responsibilities also play a significant role in the management of national parks. In dealing with complex and variable management situations, appropriate discretionary responsibilities can provide managers with a degree of flexibility and autonomy, helping to improve management efficiency and quality. Therefore, it is necessary to clearly define the scope and conditions for the exercise of discretionary responsibilities in laws and regulations. This not only safeguards the authority of managers but also regulates and constrains the exercise of such power. China should fully leverage the successful experiences of developed countries while considering its own national circumstances. By strengthening the policy system, enhancing local government autonomy, and reasonably applying discretionary responsibilities, China can promote the healthy, orderly, and sustainable development of its national parks.

2.4. Literature Review

Research on the national park system in China remains largely theoretical [66–68]. Scholars have yet to use the principal–agent model to analyze the national park system, with the exception of those studies that analyze the incentive mechanisms of ecological compensation in key national ecological function zones [69,70]. Given the uniqueness of national park management, the advancement of ecological and environmental protection and the reasonable utilization of resources need to be supported by the central government and the external ecological conservation atmosphere, compounding the complexity of the principal–agent relationship between the central and local governments in national park management. Accordingly, this study uses the multi-task principal–agent model to analyze the effort levels of local National Park Administration processes (ecological protection and resource utilization) and the central government (incentive strategies) to achieve Pareto-optimal improvement in national park management.

From the initial proposal in 2013 to the public consultation phase in 2022, the development of the national park system made significant strides. However, its growth path is still accompanied by a series of challenges and issues. This centrally delegated dual management aims to enhance the operational efficiency of national parks. Nonetheless, fine-tuning management strategies to improve their effectiveness remains an area for further exploration. Additionally, as a new category of nature reserve, the integration of national parks with existing protection systems requires thorough research. Finding a clear and efficient balance of responsibilities and collaboration between the central and local governments is a core area of national park system research. Ensuring the stability, efficiency, and sustainability of the system is a key future goal. China's practices and experiences also provide valuable insights for other countries, offering new perspectives and strategies for balancing global ecological protection and economic development.

3. Construction of the National Park Management Contract Model

3.1. Model Assumptions

Based on traditional principal–agent theory and considering the actual circumstances of China's hierarchical national park management system, this study focused on the central government and local National Park Administration processes. By adopting a multi-task principal–agent perspective, this study analyzed the impact of the external socio-ecological protection atmosphere and the central government's incentive and guidance functions on the local National Park Administration processes' management of national parks. The term "ecological conservation atmosphere" refers to the degree of emphasis placed on ecological conservation by society, government, and the public in a specific area, as well as the related actions taken. This concept encompasses multiple aspects: (1) public awareness and participation levels; (2) government support for ecological conservation at the policy level; (3) the extent of education and publicity efforts; (4) specific ecological conservation actions undertaken by communities or local groups; and (5) corporate social responsibility initiatives. The ecological conservation atmosphere reflects the overall environment and context for ecological conservation in a region, including policy, social awareness, and practical actions. A stronger ecological conservation atmosphere typically indicates greater investment and effectiveness in ecological conservation efforts in that area. The ecological conservation atmosphere coefficient is used to quantify and evaluate the effectiveness of these conservation efforts. This coefficient can be derived from various indicators such as public participation rates, government policy implementation, educational outreach programs, and corporate environmental measures [71–73].

In doing so, this study makes the following assumptions.

3.1.1. Assumption 1

First, this study operated on the assumption that the central government entrusts local National Park Administration processes with two tasks: ecological environment protection and reasonable resource utilization.

In this study, the effort level of local National Park Administration processes in ecological protection in national parks is denoted by e_1, where $e_i \geq 0$. The effort level in resource utilization is denoted by $e_2 = \alpha e_1$. As the limited use of national park resources is based on ecological protection, there exists a management progression coefficient, α, which dictates that the combined effort in resource utilization is $e_2 = \alpha e_1$. The marginal benefits of ecological protection and resource utilization are r_1 and r_2, respectively. The development of national parks is affected by external ecological environmental factors, such as the uncertainty of rainfall and temperature, forming the exogenous variables θ_1 and θ_2 for the implementation of ecological protection and resource utilization. These exogenous variables follow a normal $\left(0, \sigma_1^2\right)$ and random distribution $\left(0, \sigma_2^2\right)$, where σ_1 and σ_2 represent the uncertainties in these external variables. Based on the effort and exogenous variables, the output benefit of the national park is $\omega = \omega_1 + \omega_2$, where the benefit functions for ecological protection and resource utilization are $\omega_1 = r_1 e_1 + \theta_1$ and $\omega_2 = r_2 e_2 + \theta_2$, respectively. The distribution function of ω satisfies the monotone likelihood ratio property and the convexity condition.

3.1.2. Assumption 2

Second, this study assumed that the central government plays a guiding role in ecological protection within national parks. The central government formulates and implements the policy framework for national parks, thereby guiding the enforcement of strict ecological protection measures. In doing so, the government seeks to maintain the pristine state and integrity of the country's natural ecosystems in national parks while protecting and ensuring their multi-functional services, such as research, education, and recreation. At the same time, the central government actively guides local National Park Administration processes in the reasonable utilization of national park resources, with the goal of facilitating and improving the sustainable and comprehensive development of national parks [74].

In this study, the central government's guidance intensities for ecological protection and resource utilization are k_1 and k_2, respectively. The random errors caused by external factors are denoted by π, which follows a normal $(0, \sigma_3^2)$ distribution, where σ_3 represents the variable of external uncertainties. Consequently, the provision of guided support for local National Park Administration processes is captured by $S_k = k_1 e_1 + k_2 e_2 + \pi$. The external ecological protection atmosphere coefficient is determined by the effort levels of national parks and the central government's guidance intensity. It reflects the central and local governments' guidance in the medium- and long-term development planning of national parks, including the provision of any corresponding support, the ecological protection of green spaces and clean water, the efficiency of fiscal fund allocation, and governance capacity over national parks. At this point, local National Park Administration processes receive amplified support, μS_k, under the central government's guidance, where μ represents the external ecological protection atmosphere coefficient.

3.1.3. Assumption 3

Third, "complete rationality" permeates the game process of the relationship between the central government and local National Park Administration processes. Where the central government's strategy is characterized by risk neutrality, national parks tend to exhibit risk aversion.

When the benefits of the national park management system are unstable and the utility level of the national parks is difficult to ascertain, the von Neumann–Morgenstern utility function can be incorporated to maximize the expected utility. The equation $\rho = -e^{-\beta F}$ represents the utility function, where β is the coefficient of risk aversion. A higher value of β indicates that the agent—in this case, represented by the local National Park Administration processes—is more risk-averse. F denotes the income received by the local National Park Administration processes.

3.1.4. Assumption 4

Fourth, local National Park Administration processes incur effort costs. In this study, these costs are denoted as $C(e) = g_1 + g_2 + \frac{x_1}{2} e_1^2 + \frac{x_2}{2} e_2^2$, where g_1 and g_2 represent the fixed inputs for ecological protection and resource utilization (e.g., basic construction projects and ecological environment protection), respectively, and x_1 and x_2 are the variable cost coefficients for ecological protection and resource utilization, respectively. The effort cost function of the local National Park Administration processes is a monotonic convex function. The risk cost of the local National Park Administration processes, $R(F) = \frac{1}{2} \beta Var(F)$, is positively correlated with their risk aversion coefficient. The central government's guidance cost is denoted as $C(k) = y_1 k_1 + y_2 k_2$, where y_1 and y_2 are the contract functions for ecological protection and resource utilization, respectively.

3.2. Equations

This study calculated the incentive compensation for national parks as follows:

$$D(\omega) = Z_1 + Z_2 + \gamma_1 \omega_1 + \gamma_2 \omega_2 + \mu S_k \tag{1}$$

In Equation (1), Z_1 and Z_2 represent the fixed incentive compensations that the central government provides to the local National Park Administration processes for ecological protection and resource utilization, respectively, including fiscal transfers, subsidies, and other financial support from the central government to the local administrations. The variables γ_1 and γ_2 denote the incentive intensities for the two tasks—ecological protection and resource utilization—assigned to local National Park Administration processes by the central government.

Based on the aforementioned assumptions, the revenues obtained by local National Park Administration processes from ecological protection and resource utilization were calculated as follows:

$$\begin{aligned} U = D(\omega) - C(e) &= Z_1 + Z_2 + \gamma_1\omega_1 + \gamma_2\omega_2 + \mu S_k - g_1 - g_2 - \tfrac{x_1}{2}e_1^2 - \tfrac{x_2}{2}e_2^2 \\ &= Z_1 + Z_2 + \gamma_1 r_1 e_1 + \gamma_1\theta_1 + \gamma_2 r_2 e_2 + \gamma_2\theta_2 + \mu k_1 e_1 + \mu k_2 e_2 + \mu\pi - g_1 - g_2 - \tfrac{x_1}{2}e_1^2 \\ &\quad - \tfrac{x_2}{2}e_2^2 \end{aligned} \tag{2}$$

Given that local National Park Administration processes exhibit risk-averse characteristics, their final income can be expressed as the certainty equivalent income, $C_E(F)$. This was calculated as the difference between the expected income, $E(F)$, and the risk cost, $R(F)$, they incur, represented as $C_E(F) = E(F) - R(F)$.

On the basis of Equation (2) and Assumptions (1), (2), and (4), this study obtained the following equations:

$$E(F) = Z_1 + Z_2 + \gamma_1 r_1 e_1 + \gamma_2 r_2 e_2 + \mu k_1 e_1 + \mu k_2 e_2 - g_1 - g_2 - \frac{x_1}{2}e_1^2 - \frac{x_2}{2}e_2^2 \tag{3}$$

$$R(F) = \frac{\beta}{2}(\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2 + \mu^2\sigma_3^2) \tag{4}$$

Based on the foregoing, this study constructed Equation (5):

$$C_E(F) = E(F) - R(F) = Z_1 + Z_2 + \gamma_1 r_1 e_1 + \gamma_2 r_2 e_2 + \mu k_1 e_1 + \mu k_2 e_2 - g_1 - g_2 - \frac{x_1}{2}e_1^2 - \frac{x_2}{2}e_2^2 - \frac{\beta}{2}(\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2 + \mu^2\sigma_3^2) \tag{5}$$

Under the conditions of implementing the strictest ecological protection measures, the revenue, C, obtained by the central government can be expressed as the difference between the benefits from ecological protection and the expenditures from contractual agreements and guidance costs. Based on Assumptions (1) and (4) and Equation (1), the expression for C was determined as follows:

$$C = \omega - D(\omega) - C(k) = r_1 e_1 + \theta_1 + r_2 e_2 + \theta_2 - Z_1 - Z_2 - \gamma_1(r_1 e_1 + \theta_1) - \gamma_2(r_2 e_2 + \theta_2) - \mu(k_1 e_1 + k_2 e_2 + \pi) - y_1 k_1 - y_2 k_2 \tag{6}$$

Given that the central government's strategy in the game process is characterized by risk neutrality, its expected revenue can be calculated as $E(C)$. Based on Equation (6), this can be expressed as follows:

$$E(C) = r_1 e_1 + r_2 e_2 - Z_1 - Z_2 - \gamma_1 r_1 e_1 - \gamma_2 r_2 e_2 - \mu k_1 e_1 - \mu k_2 e_2 - y_1 k_1 - y_2 k_2 \tag{7}$$

In the national park management contract, the central government attempts to align its policy goals with the welfare objectives of local National Park Administration processes through contract design. As such, the central government seeks to maximize the expected benefits of its policies, while local National Park Administration processes aim to maximize their own certainty of returns.

Two constraint variables influence optimization: the incentive compatibility constraint (*IC*) and the participation rationality constraint (*IR*). *IC* refers to the optimal effort level that local National Park Administration processes adopt based on their certainty of benefits, while IR indicates that the certainty of benefits obtained by local National Park Administration processes must exceed their reservation utility (*R**). Therefore, this study developed the following model of the ecological environment management contract for local National Park Administration processes:

$$\begin{aligned} &\max_{(\gamma_1,\gamma_2,\mu)} E(C), \\ &IC: \ s.t. \max_{e_1} C_E(F), \\ &IR: \ C_E(F) \geq R^*. \end{aligned} \tag{8}$$

By drawing on Equations (5) and (7), this study constructed the national park management contract model as follows:

$$\begin{aligned} &\max_{(\gamma_1,\gamma_2,\mu)} r_1e_1 + r_2e_2 - Z_1 - Z_2 - \gamma_1 r_1 e_1 - \gamma_2 r_2 e_2 - \mu k_1 e_1 - \mu k_2 e_2 - y_1 k_1 - y_2 k_2 \\ &s.t. \max_{e_1} \begin{array}{c} Z_1 + Z_2 + \gamma_1 r_1 e_1 + \gamma_2 r_2 e_2 + \mu k_1 e_1 + \mu k_2 e_2 - f_1 - f_2 - \frac{x_1}{2}e_1^2 - \frac{x_2}{2}e_2^2 \\ -\frac{\beta}{2}(\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2 + \mu^2\sigma_3^2) \end{array} \\ &\begin{array}{c} Z_1 + Z_2 + \gamma_1 r_1 e_1 + \gamma_2 r_2 e_2 + \mu k_1 e_1 + \mu k_2 e_2 - f_1 - f_2 - \frac{x_1}{2}e_1^2 - \frac{x_2}{2}e_2^2 \\ -\frac{\beta}{2}(\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2 + \mu^2\sigma_3^2) \end{array} \geq R^*. \end{aligned} \tag{9}$$

3.3. Solution to the Model

In order to maximize the expected revenue of local National Park Administration processes, under the constraint of incentive compatibility, the optimal effort level is determined by the first-order condition, $\frac{\partial C_E(F)}{\partial e_1} = 0$, of *IC*. In this study, the optimal effort level for local National Park Administration processes was determined as follows:

$$e_1^* = \frac{\gamma_1 r_1 + \gamma_2 r_2 \alpha + \mu k_1 + \mu k_2 \alpha}{x_1 + x_2 \alpha^2} \tag{10}$$

Equation (11) was obtained by substituting e_1^* into the participation constraint *IR* of model (8) and by assuming that the reservation revenue, R^*, for the local National Park Administration processes is zero:

$$Z_1 + Z_2 = -\left(\gamma_1 r_1 e_1 + \gamma_2 r_2 \alpha e_1 + \mu k_1 e_1 + \mu k_2 \alpha e_2 - f_1 - f_2 - \frac{x_1}{2}e_1^2 - \frac{x_2}{2}e_2^2 - \frac{\beta(\gamma_1^2\sigma_1^2 + \gamma_2^2\sigma_2^2 + \mu^2\sigma_3^2)}{2}\right) \tag{11}$$

Substituting Equations (10) and (11) into the objective function of model (9) and solving for the first derivative of the objective function allows us to determine the optimal incentive intensity. Principal–agent contracts are typically influenced by exogenous variables, which also need to be solved for and evaluated. In the contract, although the central government cannot determine changes in the external ecological protection atmosphere coefficient, this coefficient, as an exogenous variable, significantly influences the contract setup and further affects the effectiveness of the central government's strategic guidance. Therefore, the central government aims to achieve the optimal external ecological protection atmosphere coefficient. To this end, this study computed the first partial derivative of the objective function in model (9) as follows: $\frac{\partial E}{\partial \gamma_1} = 0$, $\frac{\partial E}{\partial \gamma_2} = 0$, $\frac{\partial E}{\partial \mu} = 0$.

Therefore, the optimal incentive intensity for the central government was determined as follows:

$$\gamma_1 = \frac{{r_1}^2 + r_1 r_2 \alpha(1 - r_2) - (k_1 r_2 + k_2 \alpha r_1)\mu}{(x_1 + x_2\alpha^2)\beta\sigma_1^2 + r_1^2} \tag{12}$$

$$\gamma_2 = \frac{r_2^2\alpha^2 + r_1 r_2 \alpha(1 - r_2) - (k_1 r_2 + k_2 \alpha r_1)\mu}{(x_1 + x_2\alpha^2)\beta\sigma_1^2 + r_1^2} \tag{13}$$

This study constructed Equation (14) to solve for the external ecological protection atmosphere coefficient:

$$\mu = \frac{\left[k_1(r_1+r_2)\alpha + k_2\left(\alpha r_1 + \alpha^2 r_2\right)\right] - \left[(r_1 k_1 + r_1 k_2 \alpha)\gamma_1 + \left(\alpha r_2 k_1 + r_2 k_2 \alpha^2\right)\gamma_2\right]}{(x_1 + x_2\alpha^2)\beta\sigma_3^2 + (k_1 + k_2\alpha)^2} \tag{14}$$

This study first solved Equations (12)–(14). Once the solutions satisfied the conditions $\frac{\partial^2 C_E(F)}{\partial e_1^2} < 0$, $\frac{\partial^2 E}{\partial \gamma_1^2} < 0$, $\frac{\partial^2 E}{\partial \gamma_2^2} < 0$, this study substituted these results into Equation (10) to calculate e_1^*.

The final national park management contract is designated as A.

$$e_1^* = \frac{(r_1 + r_2\alpha)\left[r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2\right]}{(x_1 + x_2\alpha^2)\left[(x_1 + x_2\alpha^2)\beta\sigma_1^2\sigma_2^2\sigma_3^2 + r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2\right]} \tag{15}$$

$$\gamma_1 = \frac{(r_1 + r_2\alpha)r_1\sigma_2^2\sigma_3^2}{(x_1 + x_2\alpha^2)\beta\sigma_1^2\sigma_2^2\sigma_3^2 + r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2} \tag{16}$$

$$\gamma_2 = \frac{(r_1 + r_2\alpha)r_2\alpha\sigma_2^2\sigma_3^2}{(x_1 + x_2\alpha^2)\beta\sigma_1^2\sigma_2^2\sigma_3^2 + r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2} \tag{17}$$

$$\mu = \frac{(r_1 + r_2\alpha)(k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2}{(x_1 + x_2\alpha^2)\beta\sigma_1^2\sigma_2^2\sigma_3^2 + r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2} \tag{18}$$

4. Analysis of the Principal–Agent Model

4.1. Relationship between the Central Government's Incentive Level and the Local National Park Administration Processes' Ecological Protection Atmosphere Coefficient

4.1.1. Proposition 1

This study proposes that there is a substitution relationship between the incentive level of the central government and the ecological protection atmosphere coefficient of the local National Park Administration processes. There is also certain substitutability between the central government's incentives for ecological protection and the resource utilization of the local National Park Administration processes.

From Equations (12) and (13), it can be inferred that as μ increases, γ_1 and γ_2 decrease, and as μ decreases, γ_1 and γ_2 increase. Therefore, Proposition 1 is supported.

4.1.2. Implications of Proposition 1

The substitution relationship between incentives and atmosphere plays a significant role in promoting the management capacity of local National Park Administration processes. When the external ecological protection atmosphere intensifies, the central government should reduce the scale of incentives appropriately. Conversely, when the external ecological protection atmosphere diminishes, the central government should increase the scale of incentives appropriately. This approach maintains balance and facilitates the local National Park Administration processes' ecological protection of national parks.

First, based on Equation (14), when γ_1 and γ_2 are both zero, there is an upper limit of $\frac{k_1(r_1+r_2\alpha)+k_2(\alpha r_1+\alpha^2 r_2)}{(x_1+x_2\alpha^2)\beta\sigma_3^2+(k_1+k_2\alpha)^2}$ for μ. This means that the support provided by the ecological protection atmosphere has its limits, and its continuous improvement still relies on the central government's level of incentives. Therefore, the support from the ecological protection atmosphere is interval-dependent, whereas the central government's incentives are long-term. Clearly, the central government's incentives are a core and irreplaceable element in advancing the effectiveness of national park management.

Second, based on Equations (12), (13), (16), and (17), it is evident that the incentive intensities γ_1 and γ_2 are decreasing functions, that $\gamma_1 \geq 0$, and that $\gamma_2 \geq 0$ as well. This indicates that the two incentive strategies of the central government are, in the long term, effective and mutually restraining. Based on the progress of ecological protection and resource utilization by the local National Park Administration processes, the central government should allocate the two incentives appropriately in order to effectively enhance policy efficiency.

4.2. Factors Influencing the Central Government's Incentive Level and the Ecological Protection Atmosphere Coefficient

4.2.1. Proposition 2

The incentive intensities γ_1 and γ_2 of the central government and the ecological protection atmosphere coefficient μ are negatively correlated with the external uncertainty factors σ_1^2, σ_2^2, and σ_3^2; the variable cost coefficients x_1 and x_2; and the local National Park Administration processes' risk aversion coefficient β. Moreover, γ_1 and γ_2 are also negatively correlated with the guiding intensities k_1 and k_2.

The monotonic analysis of Equations (12)–(14) indicates that both the central government's incentive level and the ecological protection atmosphere coefficient are decreasing functions of external uncertainty factors (the local National Park Administration processes' variable cost coefficients and the risk aversion coefficient). The analysis also shows that the central government's incentive intensity is a decreasing function of the guiding intensity. Therefore, Proposition 2 is supported.

4.2.2. Implications of Proposition 2

First, the central government should appropriately increase the incentive intensity to effectively guide the local administrations and stimulate investments in ecological protection, successfully enhancing the ecological protection atmosphere through the transparent and open management activities of local park administrations.

Second, under the conditions of high fixed investments and low variable costs, the central government should provide certain incentive support and advance the protection of habitats and the utilization of resources by local National Park Administration processes. As the management of national parks progresses and variable costs increase rapidly, local administrations will avoid "exiting" due to substantial initial investments, performance considerations, and sunk-cost effects. Considering the subjective initiative involved in management, the central government should reduce incentives to achieve the "phasing out" of incentives.

Third, a higher risk aversion coefficient indicates an increased fear of risk among local National Park Administration processes. Therefore, the central government should begin with low incentive intensity to assess whether local administrations will continue to manage national parks effectively in the next phase. Regardless of whether the risk aversion coefficient is high, if local administrations still actively advance the management process, they will receive ample central government incentives and ecological protection atmosphere support.

Fourth, it will become easier to obtain external support for ecological protection in terms of funding and human resources as the central government's initial guidance costs increase and the ecological protection atmosphere improves. At this point, the central government can reduce its incentive expenditure.

4.3. Factors Affecting the Effort Levels of Local National Park Administration Processes

4.3.1. Proposition 3

The effort levels e_1 and e_2 of local National Park Administration processes in ecological protection and resource utilization are negatively correlated with the variable cost coefficients x_1 and x_2 and the risk aversion coefficient β.

Based on the monotonicity of Equation (15), it is evident that the effort levels e_1 and $e_2(\alpha e_1)$ of local National Park Administration processes in managing national parks are decreasing functions of the variable cost coefficients x_1 and x_2 and the risk aversion coefficient β. Therefore, Proposition 3 is supported.

4.3.2. Implications of Proposition 3

First, under conditions of increased risk aversion or rising variable costs, the effort levels of local National Park Administration processes in managing national parks will decline. Therefore, local National Park Administration processes need to address key issues in the management process promptly, streamline their operations, reduce variable costs, and mitigate reduced management enthusiasm due to high variable costs.

Second, in conjunction with Proposition 2, although the risk aversion coefficient is high and the variable costs are substantial, if local National Park Administration processes still actively participate in the management of national parks, the central government should increase the intensity of incentives to support the construction of national parks. Through the joint efforts of the central government and local National Park Administration processes, national park management can consistently maintain high standards and levels of effort.

4.4. Comparative Static Analysis of the Central Government's Incentive Level and the Ecological Protection Atmosphere Coefficient

Based on Equations (16)–(18), the optimal incentive intensities γ_1 and γ_2 and the optimal ecological protection atmosphere intensity μ are influenced by the marginal benefits of ecological protection, the ecological protection progression coefficient, the variable cost coefficients, the risk aversion coefficient, the guidance intensity coefficient, and exogenous random factors. The relationship among incentive intensity, the ecological protection atmosphere coefficient, and the marginal benefits of ecological protection merits further exploration. Accordingly, this study utilized comparative static analysis to examine the effects of incentive intensity and the ecological protection atmosphere coefficient on the marginal benefits of ecological protection.

4.4.1. Comparative Static Analysis of the Incentive Intensity (γ_1) for National Park Ecological Protection

This study derived Equations (19) and (20) from Equation (16):

$$\frac{\partial \gamma_1}{\partial r_1} = \frac{\sigma_2^2\sigma_3^2\left[(2r_1 + r_2\alpha)A - 2(r_1 + r_2\alpha)r_1^2\sigma_2^2\sigma_3^2\right]}{X^2} \tag{19}$$

$$\frac{\partial \gamma_2}{\partial r_2} = \frac{\alpha r_1^2\sigma_2^2\sigma_3^2\left[\left(x_1 + x_2\alpha^2\right)\beta\sigma_1^2\sigma_2^2\sigma_3^2 + r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2 - 2(r_1 + r_2\alpha)r_2\alpha\sigma_1^2\sigma_3^2\right]}{X^2} \tag{20}$$

From Equations (19) and (20), it is difficult to discern the trend of the changes in the marginal benefits for national park ecological protection and resource utilization, denoted as r_1 and r_2, respectively. However, there exists an r_0 such that if $r_2 > r_0$ and $r_1 \ll r_0$, then $\frac{\partial \gamma_1}{\partial r_1} > \frac{\partial \gamma_1}{\partial r_2}$ holds true. In this scenario, γ_1 is influenced more by r_1 than by r_2, indicating that marginal benefits have a significant impact on the central government's incentive intensity for ecological protection in local national parks. Even if the marginal benefit of resource utilization exceeds that of ecological protection, national parks need to advance strict ecological protection to continue receiving high ecological protection incentives.

4.4.2. Comparative Static Analysis of the Incentive Intensity (γ_2) for National Park Resource Utilization

This study obtained Equations (21) and (22) from Equation (17):

$$\frac{\partial \gamma_2}{\partial r_1} = \frac{\alpha r_2\sigma_1^2\sigma_3^2\left[\left(x_1 + x_2\alpha^2\right)\beta\sigma_1^2\sigma_2^2\sigma_3^2 + r_1^2\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1 + k_2\alpha)^2\sigma_1^2\sigma_2^2 - 2(r_1 + r_2\alpha)r_2\alpha\sigma_1^2\sigma_3^2\right]}{X^2} \tag{21}$$

$$\frac{\partial\gamma_2}{\partial r_2} = \frac{\sigma_1^2\sigma_3^2\left[(r_1+2r_2\alpha)\alpha D - 2(r_1+r_2\alpha)r_2^2\alpha^3\sigma_1^2\sigma_3^2\right]}{X^2} \quad (22)$$

In Equations (21) and (22), the trend of the changes in the marginal benefits for national park ecological protection and resource utilization, r_1 and r_2, respectively, cannot be observed directly. However, there exists an r_0^* such that if $r_1 > r_0^*$ and $r_2 \ll r_0^*$, then $\frac{\partial\gamma_2}{\partial r_1} < \frac{\partial\gamma_2}{\partial r_2}$ holds true. In this case, γ_2 is stimulated less by r_1 than by r_2, indicating that the marginal benefit of ecological protection has a greater impact on the central government's incentive intensity for resource utilization in national parks. Under conditions where the marginal benefit of resource utilization is less than that of ecological protection, the central government should apply stronger incentives to encourage stricter ecological protection. The central government should introduce incentives in a timely manner and handle the substitutive relationship between the two incentives wisely in order to prevent any adverse effects on the progress of ecological protection by local National Park Administration processes.

4.4.3. Comparative Static Analysis of the External Ecological Protection Atmosphere Coefficient

This study obtained Equations (23) and (24) from Equation (18):

$$\frac{\partial\mu}{\partial r_1} = \frac{(k_1+k_2\alpha)^2\sigma_1^2\sigma_2^2\left[(x_1+x_2\alpha^2)\beta\sigma_1^2\sigma_2^2\sigma_3^2 - (r_1^2+2r_1r_2\alpha)\sigma_2^2\sigma_3^2 + r_2^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1+k_2\alpha)^2\sigma_1^2\sigma_2^2\right]}{X^2} \quad (23)$$

$$\frac{\partial\mu}{\partial r_2} = \frac{\alpha(k_1+k_2\alpha)^2\sigma_1^2\sigma_2^2\left[(x_1+x_2\alpha^2)\beta\sigma_1^2\sigma_2^2\sigma_3^2 - (r_2^2+2r_1r_2\alpha)\sigma_2^2\sigma_3^2 + r_1^2\alpha^2\sigma_1^2\sigma_3^2 + (k_1+k_2\alpha)^2\sigma_1^2\sigma_2^2\right]}{X^2} \quad (24)$$

From Equations (23) and (24), the trend of the changes in the marginal benefits r_1 for ecological protection and r_2 for resource utilization due to the external ecological protection atmosphere coefficient μ cannot be observed directly. However, there exist an r_x and r_x^* such that if $r_1 > r_x$ and $r_2 > r_x^*$, then $\frac{\partial\mu}{\partial r_1} < 0$ and $\frac{\partial\mu}{\partial r_2} < 0$ hold. This suggests that as the marginal benefits from various efforts in national parks increase, both ecological protection and resource utilization see incremental benefits, but the external ecological protection atmosphere gradually diminishes, leading to a decline in external ecological input. Therefore, the support from the external ecological protection atmosphere is temporary and phase-dependent.

5. Analysis of Optimal Incentive Strategies

The management activities of local National Park Administration processes can be divided into three stages: a stage of strict ecological protection, a stage driven by ecological protection but including limited resource utilization, and a stage of reasonable resource utilization stage. In these three stages, the central government incentives are key to forming the national park management contract. In a Python 3.9 environment using PyCharm 2023.1.2CE, this study created graphs illustrating the function of the marginal benefits of local National Park Administration processes' ecological protection and ecological protection progression coefficients on incentive intensity. These graphs allow more intuitive observations of the impact of changes in the related coefficients on incentive strength.

5.1. Changes in Incentive Intensity during the First Stage

During the first stage, in which local National Park Administration processes focus on ecological protection, the central government seeks to maintain the effort levels of the administrations through effective strict ecological protection incentive intensity γ_1 for national parks. To this end, the fixed investment g_1 for strict ecological protection is significant, while the variable cost coefficient x_1, marginal benefits r_1, and central government's guidance intensity k_1 are relatively low. Figure 2 depicts the variations in incentive intensity γ_1 when assuming that $\alpha = 0$, $k_1 = 1$, $k_2 = 0$, $x_1 = 1$, $x_2 = 0$, and $r_2 = 0$; the risk aversion coefficient, β, and external uncertainty factors, σ_1, σ_2, and σ_3, are 1; and r_1 fluctuates at a low level (0–3).

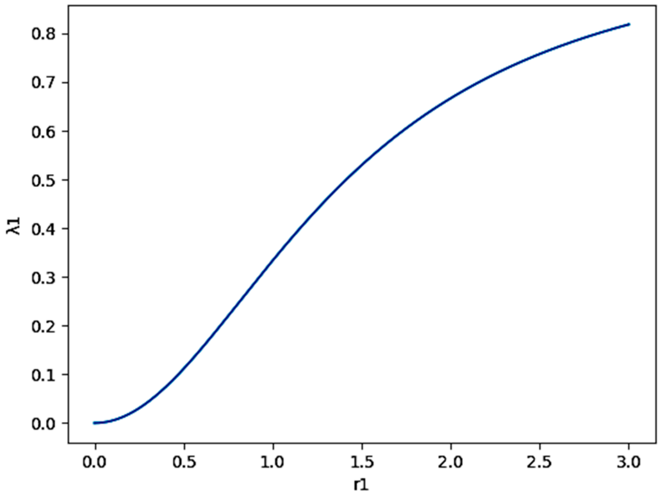


Figure 2. In this figure, γ_1 changes with r_1.

As Figure 2 shows, while the incentive strength γ_1 for strict ecological protection increases with the marginal benefit r_1, the rate of increase undergoes a process of slow acceleration, rapid rising, and gradual weakening, producing a specific slope. In the initial stages of establishing national parks, the central government budget is limited, as are the incentives they provide. As the management policies of the national parks become more defined, the central government gradually increases its incentives. When the marginal benefits of ecological protection decrease, the central government's incentives diminish.

5.2. Changes in Incentive Strength during the Second Stage

With financial investments in the first stage, local National Park Administration processes begin to advance limited resource utilization stimulated by the central government's resource utilization incentive, γ_2. In this second stage, the benefits derived from the first stage gradually peak before decreasing, as do the variable cost coefficients and central government guidance strength. Meanwhile, the benefits from limited resource utilization steadily increase, and the corresponding variable cost coefficients and central government guidance intensity are further enhanced. Figures 3 and 4 illustrate the changes in incentive intensities γ_1 and γ_2 under the assumptions that $0< \alpha < 1$, $k_1 = 7$, $k_2 = 5$, $x_1 = 7$, and $x_2 = 5$; that the risk aversion coefficient β and external uncertainty factors σ_1, σ_2, and σ_3 are 1; and that r_1 and r_2 fluctuate at a high level (4–8).

In Figure 3, when $\alpha < 1$, the incentive γ_1 for the strictest ecological protection remains at a high level and increases slightly; it then gradually decreases as the ecological protection progression coefficient rises, but it always remains greater than γ_2. The incentive strength γ_2 for limited resource use rises quickly but remains relatively low. When $\alpha = 1$, γ_1 and γ_2 tend to be similar, indicating that the central government provides nearly equal incentives for both tasks assigned to local National Park Administration processes. However, in reality, the central government provides stronger guidance for strict ecological protection (assuming $k_1 > k_2$), taking on more responsibility and investment to ensure that the national park makes steady progress in meeting its ecological protection goals.

In Figure 4a, as the marginal benefit, r_1, increases, both γ_1 and γ_2 increase in correspondence. However, the increase in γ_1 is significantly greater than that in γ_2, indicating that the advancement of ecological protection in national parks helps local administrations gain central government incentives for ecological protection. In Figure 4b, as the marginal benefit, r_1, increases, both γ_1 and γ_2 rise correspondingly. However, the increase in γ_2 is significantly greater than that in γ_1, indicating that increased resource utilization results in an increase in incentives for ecological protection.

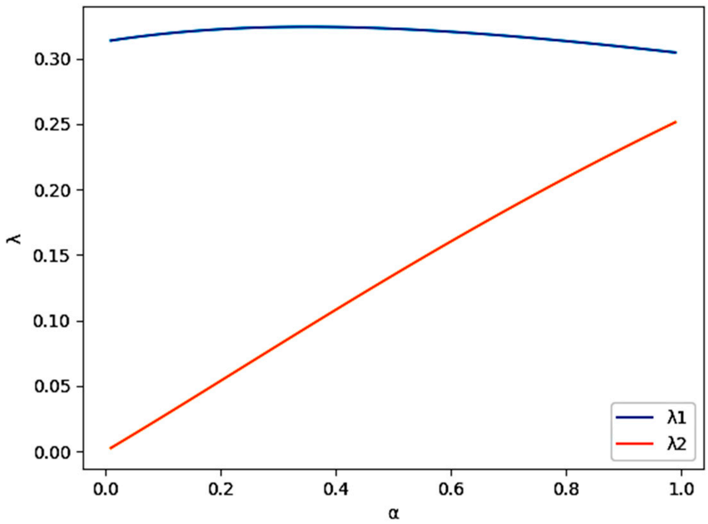
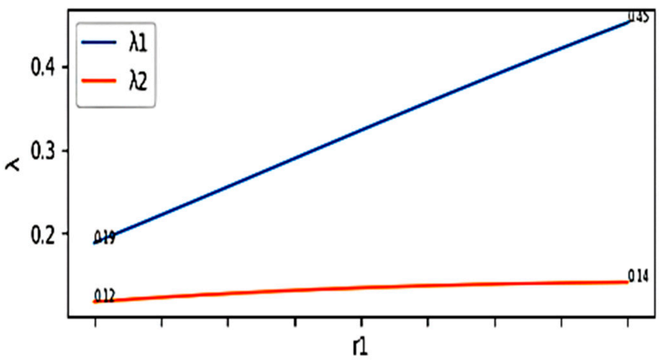
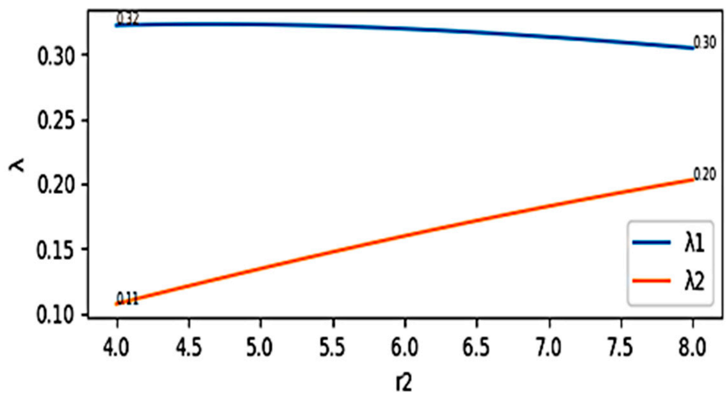


Figure 3. In this figure, γ_1 and γ_2 change with α $(0 < \alpha < 1)$.



(**a**)



(**b**)

Figure 4. The incentive strength γ_1 (**a**) & γ_2 (**b**) changing with marginal revenue r_1 & r_2 $(\alpha = 0.5)$.

5.3. Changes in Incentive Strength during the Third Stage

During the third stage, in which there is reasonable resource utilization in national parks, the benefits derived from the two management advancement tasks become distinctly differentiated. The marginal benefits from ecological protection significantly decline, while the marginal benefits from reasonable resource utilization remain at a high level. The variable cost coefficients for both ecological protection and reasonable resource utilization decrease to varying degrees, with the central government placing greater emphasis on guiding effective resource utilization. Figure 5 illustrates the changes in incentive intensities

γ_1 and γ_2 under the assumptions that $\alpha > 1$, $k_1 = 5$, $k_2 = 7$, $x_1 = 5$, $x_2 = 7$, $r_1 = 3$, and $r_2 = 6$, with the risk aversion coefficient β and external uncertainty factors σ_1, σ_2, and σ_3 being equal to 1.

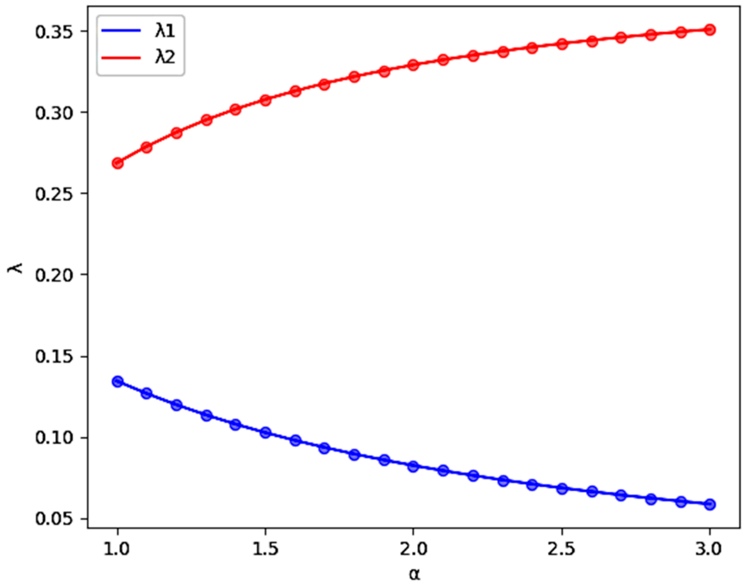


Figure 5. γ_1 and γ_2 changing with α $(\alpha > 1)$.

In Figure 5, the central government's incentives for national park ecological protection and reasonable resource utilization are starkly polarized. As the ecological protection progression coefficient increases, the gap between the two widens, approaching their respective incentive boundaries. As the management of national parks is refined, the central government adjusts the relevant incentive strategies to ensure that they align with the management behaviors of local National Park Administration processes.

5.4. Empirical Data Validation

In order to intuitively explain the impact of various internal and external factors on incentive contracts in national park management agreements and compare the interests of different parties under different information asymmetry models, we conducted a numerical study using Python. Data relevant to China's national parks were collected from public sources, such as government reports, statistical yearbooks, and the academic literature. As China's national parks are in the initial stage and the national park system has not yet been perfected, it is difficult to obtain relevant data. This study collected relevant data from China's national parks by referring to the data processing methods of relevant studies [75,76] and combining this information with open data sources (government reports, statistical yearbooks, the academic literature, etc.). Key variables, including the central government's incentive intensity, local government effort levels, and the external ecological conservation atmosphere, were selected and assigned values. Regression analysis was performed to test the theoretical model's hypotheses, and a sensitivity analysis was conducted on key parameters to assess the model's stability and robustness. This approach validated and analyzed previous research results, ensuring that our findings are grounded in empirical evidence and providing a comprehensive understanding of the dynamics within the national park management system.

In order to provide a detailed introduction to the actual data, we needed to gather information from multiple credible sources. These data include the investments made by the central and local governments in ecological protection and resource utilization, the metrics for measuring the ecological conservation atmosphere, and the actual data on the effectiveness of ecological environment protection and rational resource utilization. Table 1 shows the detailed contents and sources of these data.

Table 1. Empirical data, interpretation, and sources.

Parameter Name	Data	Data Interpretation	Data Source
Incentive intensities for ecological protection (γ_1)	563	China's total fiscal expenditure on ecological and environmental protection projects in 2023 will be about CNY 563 billion.	National Bureau of Statistics of China
Incentive intensities for resource utilization (γ_2)	320	In 2023, China's expenditure related to resource utilization, including financial input in pollution control, environmental restoration, and energy utilization, is estimated to be CNY 320 billion.	The 2023 Government Work Report and Statistical Communique issued by the National Bureau of Statistics and the Ministry of Finance of China
Effort level in ecological protection (e_1)	8	The PM2.5 concentration in Beijing, Tianjin, and Hebei Province dropped by 2.3%, effectively improving air quality. Water quality in the Yellow River basin improved from good to excellent; soil environmental risks are basically under control nationwide. Based on the significant improvement of air quality and water quality in various regions, local governments have invested a great deal of resources and effort in pollution control, and the implementation of soil pollution control and ecological restoration projects shows the importance and action power of the government in ecological protection. The reasonable estimation of local government's efforts in ecological protection (e_1) is 8 points (out of 10 points).	Report on the state of China's ecological environment; work report of the State Council; State of the Ecological Environment 2023 Report
Effort level in resource utilization (e_2)	7.5	By 2023, China had invested significant resources in the development and utilization of clean energy sources such as solar and wind power. Local governments are actively involved in the implementation and management of these projects. Local governments have invested significantly in water and air pollution control projects and have implemented a number of large-scale environmental restoration projects in soil restoration and mine reclamation; many provinces have made remarkable progress in the effectiveness of control. It can be reasonably estimated that the level of effort of local governments in resource utilization is 7.5 points (out of 10 points).	Report of the China Green Finance and Development Center; work report of the State Council
External ecological protection atmosphere coefficient (μ)	0.76	It combines social media big data and questionnaire data to understand the status quo of the public's attention to and awareness of national parks. In addition, the public environmental awareness index increased from 70.52 in 2018 to 76.81 in 2022, indicating that the public's attention to ecological protection is constantly increasing. Therefore, the ecological protection atmosphere coefficient (μ) is set to 0.76 (the full score is 1).	Research article [77] and China Daily [78]
Benefit function for ecological protection (ω_1)	9	From 2000 to 2019, the average annual net primary productivity (NPP) of protected areas generally increased. The average annual NPP increased in 95.47% of the reserves and decreased in 4.53% of the reserves. The ecological protection effect on the protected area is positive and significant on the whole. The Chinese government has taken a number of measures in ecological protection, including the "Green Shield" campaign and the establishment of the red line ecological protection system, which have effectively protected more than 90% of terrestrial ecosystem types and 85% of key wildlife populations. The ecological environmental protection effect (ω_1) can be reasonably estimated at 9 points (out of 10 points).	Research articles [75,76]

Table 1. *Cont.*

Parameter Name	Data	Data Interpretation	Data Source
Benefit function for resource utilization (ω_2)	7	The study analyzed changes in carbon storage in national parks by using the InVEST model and found that carbon storage in China's national parks has shown an overall trend of increasing over the past 30 years. This reflects the effectiveness of national parks in resource management and ecological protection. However, the national park system is still in its infancy in China; therefore, a reasonable estimate of the effect of rational use of resources (ω_2) is 7 points (out of 10 points).	Research article [79]

In order to evaluate the stability and robustness of the model, a sensitivity analysis of key parameters (γ_1, γ_2, and μ) was performed using Python's statsmodels library to evaluate the impact of different parameter changes on the model results. From the sensitivity analysis figure (Figure 6), we can observe the impact of changes in key parameters (γ_1, γ_2, and μ) on ω_1 (the effect of ecological environment protection) and ω_2 (the effect of the rational utilization of resources):

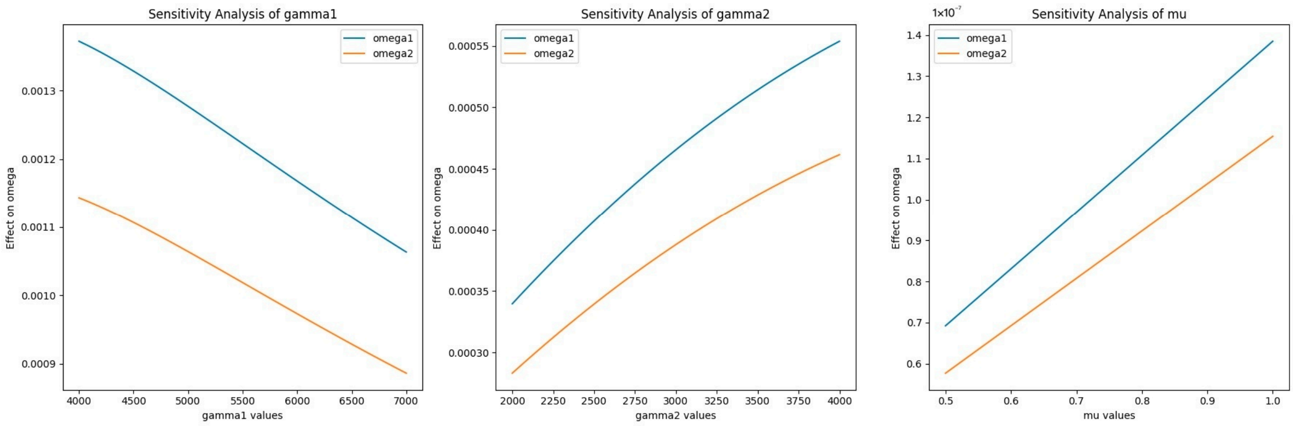


Figure 6. The impact of changes in γ_1, γ_2, and μ on ω_1 and ω_2.

The effect of γ_1 (ecological conservation incentive intensity) on ω_1 and ω_2 is as follows: 1×10^{-7}.

With an increase in γ_1, the influence coefficients of ω_1 and ω_2 decrease gradually. This indicates that the marginal effect of ecological protection incentive intensity on ecological protection and the rational use of resources is decreasing. Although γ_1 has a significant positive effect on ω_1 and ω_2, its effect gradually decreases as the incentive intensity increases.

Although improving the incentive intensity of ecological protection can improve the effect of ecological environmental protection and the rational utilization of resources, its marginal benefit will weaken as the incentive intensity increases.

The effect of γ_2 (incentive intensity of resource utilization) on ω_1 and ω_2 is as follows:

With an increase in γ_2, the influence coefficients of ω_1 and ω_2 gradually increase. This indicates that the marginal effect of the incentive intensity of resource utilization on ecological protection and the rational use of resources is increasing. Although the effect of γ_2 on ω_1 is small, its effect is enhanced as γ_2 increases.

The effect of μ (ecological conservation atmosphere) on ω_1 and ω_2 is as follows:

The influence coefficients of ω_1 and ω_2 increase significantly as μ increases. This indicates that the ecological protection atmosphere has a significant positive impact on the ecological protection and resource utilization effect, and its impact increases with the enhancement of the atmosphere.

Although improving the incentive intensity of ecological protection can improve the effect of ecological environmental protection and the rational utilization of resources, its marginal benefit will weaken with the increase in incentive intensity. Increasing the incentive intensity of resource utilization can not only significantly improve the effect of the rational utilization of resources but also gradually enhance the impact on the effect of ecological environmental protection. Creating a good environment for ecological protection plays an important role in improving the effect of ecological environmental protection and the rational utilization of resources. The analysis results basically match the theoretical model in this study and verify that the central government's incentive intensity of ecological protection, incentive intensity of resource utilization, and ecological protection atmosphere have a significant impact on the local government's ecological environmental protection and rational utilization of resources.

6. Discussion

Central government policies play a crucial role in enhancing the ecological functions and biodiversity of national parks. However, the current ecological subsidy methods from the central government are relatively singular, primarily relying on fiscal transfers for compensation. Due to the limitations of fiscal funding and decentralized management, the sustainable development of national parks faces many challenges and is difficult to effectively advance. At the local government level, while authorities must follow the overall national strategy and legal regulations to implement central policies, they also possess a certain degree of discretional responsibilities. For example, in the pilot area of Qianjiangyuan National Park, located in the relatively developed eastern coastal region of China, the central government provides financial subsidies according to fixed allocation standards. This, to some extent, weakens the motivation of local governments to actively fulfill their ecological protection duties. Although local governments can subsidize the national park pilot area through their own fiscal revenues, this may lead to local governments, driven by their own interests, passively implementing or even resisting certain policies. Consequently, this can result in the misuse of the national park's name for unauthorized resource utilization, such as eco-tourism, which undoubtedly contradicts the primary goal of ecological protection. Therefore, to promote the sustainable development of national parks, it is necessary to further improve the central government's ecological compensation mechanism and diversify compensation methods. Additionally, increasing fiscal funding and enhancing management is crucial to ensure the effectiveness and transparency of fund usage. Local governments, in implementing central policies, should adhere to the core goal of ecological protection in national parks, overcoming interest-driven motives and actively fulfilling their ecological protection responsibilities. Together, these efforts will promote the healthy development of national park ecosystems and the protection of biodiversity.

From the current progress of national park construction and the implementation of policies by provincial governments, it is evident that some national parks have not yet achieved the construction goals set for establishing a natural protected area system centered on national parks. Specifically, in certain regions, there is a lack of effective coordination between land use planning and ecological protection planning for national park construction. For example, some areas designated for tourism development overlap with core areas of national parks, leading to conflicts between planning and construction. Currently, there are several significant deficiencies in the regulatory standards of China's national park system pilot projects. On one hand, there is a lack of or inconsistency in legal bases, and different documents have varied zoning standards and methods for national parks, affecting the standardization and uniformity of national park construction [80]. On the other hand, from the relevant policy documents and actual construction of national parks, it is clear that the construction process reveals incomplete entry standards for creating a natural protected area system, and it also overlooks practical difficulties at the operational level [81]. These issues require focused attention and resolution in future efforts to ensure the smooth progress and effectiveness of national park construction.

Evidently, the current central government policies and incentive mechanisms are inadequate in balancing local governments' focus on ecological protection and resource utilization in national parks. Therefore, it is imperative to reassess and redefine the management contract mechanism for national parks. The management contract relationship between the central and local governments is crucial for balancing the sustainable development goals of national parks and ensuring the effective implementation of central policies.

This paper provides an in-depth analysis of the dual roles undertaken by the central government in the processes of incentivization and guidance, and it explores the effective contract mechanisms established by local national park management authorities in promoting ecological protection and resource utilization. By thoroughly examining the relationship between the intensity of central government incentives and the ecological conservation atmosphere coefficient, this paper identifies the key factors influencing incentive intensity, the ecological conservation atmosphere coefficient, and the effort levels of local governments, thereby offering important theoretical support for optimizing national park management strategies. Additionally, this paper systematically analyzes the three stages of national park management system development, delving into the incentive strategies adopted by the central government at different stages and their effects. Empirical verification using experiential data confirms the reliability of the theoretical model, and sensitivity analysis further reveals the stability and robustness of the model across different application scenarios. These research findings provide significant guidance for improving the management contract mechanisms of national parks, fostering collaborative efforts between central and local governments, and promoting the sustainable development of national parks.

7. Conclusions

In the management of national parks, the government focuses on advancing ecological protection and ensuring the reasonable utilization of resources. By constructing a multi-task principal–agent model between the central and local governments, this study explored the interaction between the central government's incentive intensity and the ecological protection atmosphere coefficient. In doing so, it clarified the factors influencing incentive strength, the ecological protection atmosphere, and the effort level of local National Park Administration processes, constructing a Pareto-optimal national park management contract to continuously promote the healthy development of national parks. The findings can be summarized as follows.

First, in contract management, there is a substitution relationship between the central government's incentives for ecological protection and reasonable resource utilization, and there is also a substitution relationship between the central government's incentives and the external ecological protection atmosphere. While the ecological protection atmosphere is only temporary, central government incentives should be continuous and irrevocable.

Second, the intensity of central government incentives is negatively correlated with guidance strengths k_1 and k_2, and the central government's incentive intensity and ecological protection atmosphere are negatively correlated with external uncertainty factors, the variable cost coefficients of local National Park Administration processes, and risk aversion coefficients. Increasing guidance intensity allows the central government to appropriately reduce incentive expenditures, alleviating incentive pressures. Reducing uncertainty, lowering variable costs, and controlling risks are conducive to maximizing the benefits of national park management contracts.

Third, in the management process, variable cost and risk aversion coefficients are negatively correlated with the effort level invested in national park management. This can lead to the loosening of ecological protections on the one hand and increased fear of risk on the other.

Fourth, the central government's incentive intensity for ecological protection is significantly influenced by the marginal benefits of ecological protection. National parks need to implement the strictest ecological protections to obtain higher incentives for ecological protection. At the same time, although improving the incentive intensity of ecological protection is effective, we should pay attention to the problem of diminishing marginal benefits and allocate resources rationally.

Fifth, the central government's incentive intensity for reasonable resource utilization is greatly influenced by its marginal benefits. Given the substitutive relationship between ecological protection and resource utilization incentives, the central government needs to be mindful of the necessity for strict ecological protection while advancing resource utilization, actively encouraging local National Park Administration processes to implement the strictest ecological protection processes, and carefully managing the timing of the introduction of limited resource use incentive strategies. The marginal benefit of the incentive intensity of resource utilization increases; therefore, we should make full use of this feature to improve the effect of the rational utilization of resources.

Sixth, the ecological protection atmosphere is crucial to improving the effect of ecological environmental protection and resource utilization, and the public's awareness and participation in ecological protection should be further enhanced through publicity, education, and policy guidance. However, the ecological protection atmosphere in national parks is negatively correlated with marginal benefits. As management policies advance, the support provided by the external ecological protection atmosphere gradually decreases.

Based on the foregoing research conclusions, specific measures need to be implemented at the institutional and technological levels to incentivize agents to exert more effort in the management of national parks. Given the substitutability of the two tasks, this study proposes the following measures.

First, in order to prioritize ensuring that the economic benefits of ecological protection surpass those of the commercial use of resources, the provision of key support through institutional frameworks is essential. Incentives for such activities should only be increased when the economic returns from ecological protection are significant. More specifically, the Chinese government needs to swiftly implement and gradually enforce legislation concerning national parks. In addition to clearly delineating the management responsibilities of government agencies and national parks, doing so will help prioritize ecological protection funds in budget allocation, thus limiting spending on non-ecological projects. Furthermore, in the construction of management frameworks, the weight of ecological protection indicators in the national park assessment system should be significantly enhanced. Annual and long-term evaluations of national parks should primarily focus on ecological protection effectiveness. In the performance budgeting of national park projects, an indicator system that truly reflects the quality of ecological protection should be developed, and serious budget performance evaluations should be conducted according to this system. Meanwhile, at the local level, the ecological management effectiveness of national parks should be recognized as an important metric for evaluating local governments, gradually forming a standardized national park ecological protection evaluation system.

Second, although the effectiveness of ecological protection is not as easily quantifiable as resource utilization outcomes, this does not mean that incentives for it should be reduced. Such an approach would deviate from the original intent of national parks. In order to ensure that ecological protection receives the attention and incentives it deserves, it is crucial to reduce its output unobservability. This requires enhancing the application of information technology and investing more labor and financial resources into data monitoring and the analysis of conservation efforts to improve the precision of measuring ecological protection effectiveness. Specifically, the budget for national park projects should increase investment in the construction of smart national parks, including setting up field monitoring stations, purchasing monitoring equipment, and training personnel. Technologies such as satellite remote sensing, drone monitoring, and infrared tracking should be systematically employed to monitor national parks in a comprehensive, continuous, and integrated manner from land, air, and space. Subsequent efforts should be made to establish a big data monitoring platform, improve the efficiency of field monitoring data processing, and gradually achieve precise and intelligent monitoring and early warnings, thereby promoting the comprehensive coverage of resource monitoring.

Finally, in the context of implementing a multi-task principal–agent system, the incentive goals of the central and local governments need to be coordinated effectively in order to ensure consistency between both parties' objectives. To this end, the central government should focus on direct incentive policies applied to national parks while establishing and optimizing the incentive system for local governments. Specific measures could include reforming the current fiscal transfer payment system, which undervalues the assessment of ecological protection effectiveness, and introducing a fiscal incentive mechanism centered on the ecological protection outcomes of national parks. Under this mechanism, the central government's ecological transfer payments would be adjusted based on the ecological protection performance of each region and the improvement thereof, with regions that exhibit better performance or progress receiving more financial support from the central government. This type of fiscal incentive would encourage local governments to actively participate in and advance the ecological construction of national parks.

While this study aims for depth, it does have certain limitations, which also indicate directions for future research and offer a broad space for further exploration. First, the current analysis primarily focuses on the relationship between central and local governments. However, in the actual operation and management of national parks, there are many complex principal–agent relationships, such as those between national parks and communities, enterprises, and other entities. These relationships are prevalent and significant in practice and should not be overlooked. Therefore, future research should broaden its scope to analyze the incentive contract design among multiple stakeholders more comprehensively and deeply to better reveal the incentive mechanisms within national parks. Moreover, due to the lack of a comprehensive and reliable data system in China's national park field, this study mainly relies on government work reports and related literature for data acquisition, which inevitably constrains the depth and breadth of the research. However, as the national park system continues to improve and develop, and as more precise and abundant empirical data gradually accumulate, future research will be able to fully utilize these data resources. This will allow more accurate analysis of the contractual relationships and incentive structures between different levels of government in national parks, thereby providing more solid and powerful support for the scientific management and sustainable development of national parks.

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