PROMOTIONAL POLICIES AND BEHAVIOURS OF GREEN BUILDINGS UNDER CHINA'S MULTI-LEVEL GOVERNANCE

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Promotional Policies and Behaviours of Green Buildings under China's Multi-level Governance

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CERTIFICATE OF ORIGINALITY

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Abstract

Green building (GB) promotion is essential for the sustainable transformation of the construction industry, aiming to conserve energy, reduce emissions, improve residents' welfare, save resources, and protect the environment. In China, while significant government emphasis and policy support have driven progress, information asymmetry and conflicts of interest across different levels of government in the multi-level governance (MLG) system impede GB promotion. Despite advances, the proportion of GBs in total building area remains low, falling short of the "14th Five-Year Plan" targets. Effective green building policies (GBPs) are therefore crucial.

This study investigates GBPs within China's MLG system, focusing on four objectives: (1) to examine the current state of GBPs and identify the key characteristics and challenges of GBP system in China; (2) to develop a tripartite evolutionary game model and investigate the dynamic behaviours of stakeholders and potential pathways; (3) to establish a dual principal-agent model for designing the optimal policy incentive mechanisms; and (4) to empirically verify the proposed models and propose policy implications.

First, to clarify the typical characteristics and existing shortcomings of the GBP system, this study reviewed and analysed the historical evolution of GBPs through a mixed-content analysis, highlighting three key stages of policy development, identifying the top-down nature of the policy approach, the combination of "carrot-and-stick" incentive mechanisms, and challenges related to interest conflicts, non-cooperative games, regional inequalities, and inadequate incentive mechanisms. Second, based on the characteristics of GBP system, a tripartite evolutionary game model was developed to analyse the behavioural interactions of central and local governments and developers under information asymmetry. To effectively promote GBs, the central government must exercise its leadership and regulatory role, while policy incentives at both levels should be tailored to specific contexts to form the ideal pathway. Third, to design

optimal policy incentives under information asymmetry, a dual principal-agent model was constructed to encourage green actions and uncover hidden factors that hinder GB promotion. Fourth, these models were empirically validated through survey data. Finally, policy recommendations were proposed to support large-scale, high-quality GB development primed by theoretical and empirical insights.

This study provides significant theoretical and practical contributions to understanding GB promotion within China's MLG system. Theoretically, it offers a comprehensive analysis of GBP evolution, enriching the literature with a nuanced framework for understanding policy dynamics, including intensity, structural shifts, and regional disparities. By addressing the roles and strategies of central and local governments, it fills a critical gap in the study of MLG dynamics in sustainable development. Additionally, the study introduces innovative models, such as the tripartite evolutionary game and dual principal-agent models, to analyse stakeholder interactions and incentive mechanisms, providing a context-sensitive approach to aligning interests in MLG systems. Empirical validation bridges theoretical constructs with real-world practices, enhancing robustness and applicability. Practically, the study offers actionable recommendations to refine policy coherence, foster stakeholder collaboration, and support the widespread adoption of sustainable building practices. These empirically tested strategies guide policymakers in designing adaptive, region-specific incentives for optimising GBPs within China's MLG framework.

Publications Arising from the Thesis

[1] **Hu, Q.**, Xiong, F., Shen, G. Q., Liu, R., Xue, J., Wu, H., & Zhou, X. (2024). Incentive Mechanism Design for Promoting High-Quality Green Buildings in China's Multi-Level Governance System. *Building and Environment*, 112358.

[2] **Hu, Q.**, Xiong, F., Shen, G. Q., Liu, R., Wu, H., & Xue, J. (2023). Promoting green buildings in China's multi-level governance system: A tripartite evolutionary game analysis. *Building and Environment*, *242*, 110548.

[3] **Hu, Q.**, Xue, J., Liu, R., Shen, G. Q., & Xiong, F. (2023). Green building policies in China: A policy review and analysis. *Energy and Buildings*, *278*, 112641.

[4] **Hu, Q.**, Liu, R., Su, P., Huang, J., & Peng, Y. (2023). Construction and demolition waste generation prediction and spatiotemporal analysis: a case study in Sichuan, China. *Environmental Science and Pollution Research*, *30*(14), 41623-41643.

[5] **Hu, Q.**, Xiong, F., Zhang, B., Su, P., & Lu, Y. (2022). Developing a novel hybrid model for seismic loss prediction of regional-scale buildings. *Bulletin of Earthquake Engineering*, *20*(11), 5849-5875.

[6] **Hu, Q.**, Su, P., & Xiong, F. (2021). Dynamic game strategies for construction and demolition waste recycling with learning and reference effects. *Environmental Impact Assessment Review*, *89*, 106592.

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CHAPTER 1 Introduction

1.1 Research Background

1.1.1 Why promote green building?

Over the last few decades, the building and construction sector has faced consistent criticism for its substantial contribution to global energy consumption and greenhouse gas (GHG) emissions (Ikudayisi et al., 2022). It consumed nearly 32% of the global end-use energy and was responsible for 34% of total carbon emissions (United Nations Environment Programme, 2025). The issue is even more pronounced in China, where this sector accounted for 36.3% of total energy consumption, resulting in 48.3% of its energy-related carbon emissions (China Association of Building Energy Efficiency & Chongqing University, 2025; China Association of Building Energy Efficiency & Institute of Urban-Rural Construction and Development, Chongqing University, 2023). Substantial reductions in these emissions and energy usage help to protect the environment and improve human life quality (L. Chen, Chan, Darko, et al., 2022). Therefore, to achieve sustainability, China has encountered a key challenge in saving energy and cutting emissions associated with buildings, especially with the goal of reaching carbon peaks at around 2030 and carbon neutrality at around 2060 (Z. Liu et al., 2022; Zou et al., 2017). Recognising the challenge of reducing energy consumption and GHG emissions in the building sector, green buildings (GBs) have been introduced as a possible measure to address the issue (R. Friedman & Rosen, 2022). They represent a shift within the construction industry and a symbol of China's broader commitment to sustainable development (H. Yu et al., 2024). The GBs, as defined by the World Green Building Council (WorldGBC, 2022), refer to "*the buildings in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts on our climate and natural environment*", and they have been regarded as a sustainable alternative to traditional buildings (TBs) (B.-J. He, 2019; Hwang et al., 2017).

Driven mainly by sustainability goals, GBs can mitigate the adverse effects of building stock on the economy, society and natural environment (Darko et al., 2017; Ikudayisi et al., 2022; Zuo & Zhao, 2014). Compared with TBs, GBs produced 50%, 48% and 5% less GHG associated with water consumption, solid waste management and transportation, respectively (Mozingo & Arens, 2014). In China, some GBs consume 26% less energy than TBs (Q. Shi et al., 2016). In other words, GB promotion is a key component of the construction industry's shift to sustainability (Sentman et al., 2008).

1.1.2 Why is government essential in green building promotion?

Due to the higher construction costs and uncertain market demand associated with GB, on the one hand, the construction stakeholders lack motivation and hesitate to build GB; on the other hand, buyers are unwilling to spend more (Dwaikat & Ali, 2016). Thus, the government, as the policy maker and industry supervisor, plays a leading and essential role in the development of GB in accordance with Chinese market conditions because of the public welfare nature of GB (Diyana et al., 2013; Harrington & Hsu, 2018; Ying Liu et al., 2012). The government's leading role cannot be ignored when investigating possible mechanisms for promoting GB.

In practice, the government promotes the development of GB mainly in the form of green building policies (GBPs). Policies issued by the central government, such as "*Assessment standard for GBs*" (GB/T50378-2006) and (GB/T50378-2019), "*Green Building Action Plan*" and "*Green Building Creation Action Plan*" have made significant steps for GB development in China. Put simply, China's central government released a policy system for GB development, which has fostered the development of the green construction industry and enhanced the living environment (Q. Feng et al., 2020). At the local level, most provinces enacted GB-related policies, including incentive and regulatory mechanisms, to find ways to promote GB. For instance, Guangdong, Zhejiang, Hebei, and Jiangsu introduced GB regulations to encourage GB participants and regulate their behaviours.

Although the Chinese government has launched several policies to govern GBs at both national and local levels, China's GB development process is relatively slow (Q. Feng et al., 2020). In comparison to developed countries, China still faces a great need for the development of GB (Wuni et al., 2019). Concerning this, the Chinese government has met a great policy challenge in GB promotion. There is an imperative need to investigate the current state of China's GBPs and ascertain appropriate implementation strategies for the Chinese government's policy-making to lead GB promotion.

1.1.3 Why promoting green building under China's multi-level governance is needed?

The GB, as a sustainability instrument, involves multiple public and private actors operating at different levels of governance; these actors interact with each other and form a multi-level network of governance (Elzen et al., 2004; R. Friedman & Rosen, 2022; Geels, 2011). Multi-level governance (MLG) has special relevance for sustainability efforts (Zeemering, 2012). The term MLG is used in environmental policy to describe complex interactions in policy-making and implementation and to meet the necessary needs of policies negotiated by different levels of government (Zeemering, 2012; Zen et al., 2019). Regarding the government's leading role in GB promotion, MLG implies that the engine of policy-making is the cooperation and coordination of multiple levels of government (Vantaggiato, 2020).

Local government has long been recognised as an essential actor in achieving environmental goals at local and global scales (Harrington & Hsu, 2018). This is because policy outcomes are not the product of central government decisions alone but are also shaped by local government interests (Ishtiaque, 2021; Rhodes, 1996). Given the close interlinkage between central and local, the Chinese context provides an intriguing ground in this regard (Ye & Björner, 2018). Unsurprisingly, in China's sustainable development domain, shortcomings in implementing environmental policies have been frequently observed due to the insurmountable GDPism of the local government (Marinaccio, 2019; Tanaka, 2015).

The Chinese MLG system is characterised by largely fiscal decentralisation across multi-level governments, but meanwhile has a centralised governance structure with strong top-down mandates (X. Zhang, 2006). Because deficiencies and information barriers in the MLG system and the shared policy goals among multiple government layers are not always self-evident, the Chinese governments at all levels have not yet formulated a specific and effective GB development system (Q. Feng et al., 2020; Kokx & van Kempen, 2010; Porras-Gómez, 2014). Specifically, due to political centralisation, the central government retains control over the formulation and top-down enforcement of environmental regulations (Gilley, 2012; X. Li et al., 2019). At the same time, local governments, by means of self-financing, undertake the environmental governance responsibilities entrusted by the central government against the background of fiscal decentralisation and fierce competition in local economic development (K. Zhang et al., 2017). On this basis, if economic development and environmental governance are out of balance, local governments have strong incentives to deviate from the central government's policy initiatives. Overall, political centralisation and fiscal decentralisation outline the institutional background of rights-based environmentalism with Chinese characteristics (H. Zhao & Percival, 2017). In this regard, MLG theory has helped to decipher a landscape of multiple authority-building practices in China's semi-authoritarian political system, where a one-party political system, ideological control and economic freedom coexist (Francesch-Huidobro & Mai, 2012; Mai & Francesch-Huidobro, 2014).

In the context of GB promotion, local governments are key actors in transforming central policies into various actions. As a consequence, China's MLG is a challenging framework for promoting GB, and GB promotion can be widely understood as a multi-level endeavour that requires the coordination of different levels of actors. However, few studies, if not none, have analysed the interactions among actors of various layers in GB promotion and investigated the possible implementation strategies under China's MLG framework. Thus, achieving GB promotion under China's MLG is crucial but a promising area. It is imperative to radically improve governments' capacity to actively participate in GB promotion in China at all levels. This would mean enhancing the understanding of strategic decision-makers in the context of MLG and developing policy incentive mechanisms that encourage the development of GB.

1.2 Research Scope

This study centres on GBs and China's MLG, representing a broad and interdisciplinary research domain. Nevertheless, the comprehensive coverage of all relevant aspects within this research endeavour is unattainable. Thus, it is imperative to establish a clear research scope at the beginning of the thesis.

1.2.1 Green building

This study focuses on the general concept of GB, which is distinct from traditional building practices. It emphasises sustainability, environmental friendliness, and resource efficiency. While various types of GB exist, such as residential and commercial, this study promotes GB in a broad sense, irrespective of specific building types. The objective is to promote the fundamental principles and characteristics associated with GB, contributing to adopting sustainable and environmentally responsible construction practices. This is aligned with previous research, such as the work of Fan & Hui (2020), Feng et al. (2020), Liu et al. (2022) and Qiao et al. (2022).

1.2.2 Green building policy

Policies, formulated by party and government agencies and other organisations, serve as actions and guidelines intended to achieve political, cultural, economic, social and ecological goals. These policies encompass a range of forms, including laws, regulations, measures, decisions and government documents, all aimed at advancing national and societal progress. In this study, GBPs specifically refer to policies that affect the entire lifecycle of GBs, from design and construction to operation and demolition (Matisoff et al., 2016).

1.2.3 China's multi-level governance

China's MLG in this study focuses on the central-local governance relationship, particularly between the central and provincial levels. In the Chinese political system, the Communist Party of China (CPC) holds a central leadership and decision-making role in governance, setting it apart from other countries. This unique context provides a distinct backdrop for exploring MLG (M. Schreurs, 2017). Scholars have applied the concept of MLG in the Chinese context, primarily focusing on vertical levels (Z. Huang et al., 2015; Kuhn, 2016; L. Liu et al., 2012; M. Schreurs, 2017; M. A. Schreurs, 2010). China's administrative units are organised into a multi-tiered system comprising central, provincial, municipal, county and township levels (X. Huang et al., 2016).

The term "local" has different meanings in Western and Chinese contexts. In Western countries, it typically refers to grassroots-level governments, whereas in China, it specifically designates power institutions below the central government, encompassing provinces, cities, counties, and townships (Liu S. et al., 2022). The relationship between China's central and local governments can be viewed through public administration and public governance lenses. Public administration is seen as an intergovernmental relationship, with scholars focusing on the management hierarchy of the five government levels (Jia & Bai, 2002). From the public governance perspective, a new concept of "two-level governance, five-level management" has been proposed, distinguishing the central-local relationship from the relationship among local provinces, cities, counties, and townships (Liu S. et al., 2022). The former pertains to the national level, while the latter concerns the local level. The vertical structure of national governance adheres to constitutional provisions and historical traditions, comprising the central and local levels. Power distribution among government levels is uneven, with exclusive division of powers such as legislation and judiciary between the central and local governments, without further subdivision among provincial, municipal, county, and township levels (Liu S., 2015).

This study focuses on the hierarchical analysis of intergovernmental relations, particularly the central-local relationship within the governance dimension. The term “local government” in this context encompasses four levels: provinces, cities, counties, and townships, with a primary emphasis on provincial-level governments. This scope is primarily driven by the fact that the promotion of GBs fundamentally represents a specific aspect of environmental governance. Additionally, provincial-level governments are under direct supervision and management by the central government, with limited direct connections to lower-level governments (Pan, 2018). Therefore, within the scope of this study, the central-local relationship primarily refers to the relationship between the central government and provincial-level governments. This hierarchical relationship has been extensively utilised to explore and explain various domains, such as air pollution governance (X. Sun et al., 2021), forest governance (X. Yu & Wang, 2013), coal energy transition (D. Liu et al., 2023) and the promotion of new energy vehicles (K. Li & Dong, 2022).

1.3 Research Aim and Objectives

The overall aim of this research is to explore effective GBPs for advancing the promotion of GBs within China’s MLG system. The specific research objectives are as follows.

(1) To examine the current state of GBPs and identify the key characteristics and challenges of GBP system in China.

(2) To develop a tripartite evolutionary game model and investigate the dynamic behaviours of stakeholders and potential pathways.

(3) To establish a dual principal-agent model for designing the optimal policy incentive mechanisms.

(4) To empirically verify the proposed models and propose policy implications.

1.4 Research Design

According to four specific research objectives presented in subsection 1.3, this study follows the process depicted in Figure. 1.1.

(1) First, through comprehensive literature review, research gaps are identified whilst research objectives are clear. This process will lead to the first two chapters, the introduction and literature review.

(2) In addition to the systematic literature review mentioned in Chapter 2, empirical methods such as document analysis and questionnaire survey are applied to this study principally for data collection, whereas statistical techniques, policy intensity assessment, evolutionary game theory and principal-agent theory are utilised as tools, for quantitative analysis of data. This process will lead to Chapter 3, which outlines the research design and methodology.

(3) Next, by combining content analysis and policy intensity assessment, the characteristics of GBP system are identified, and the challenges of the current GBP system are determined accordingly. This process will lead to Chapter 4, which offers a comprehensive review and analysis of GBPs in China.

(4) According to the characteristics of GBP system, a GB promotion system in the context of China's MLG is established, and the dynamic behaviours among key participants can be investigated by the evolutionary game model. This process will lead to Chapter 5, which explores the dynamic behaviours and evolutionary pathways of GB promotion.

(5) Drawing from the behavioural logic of stakeholders and the characteristics of GBP system, a dual principal-agent model can be built to determine the optimal incentive mechanisms for governments at different levels. This process will lead to Chapter 6, which focuses on the design of policy incentive mechanisms for GB promotion.

(6) Lastly, through statistical analysis, data collected from questionnaire surveys are used to

validate the previous models. Policy implications for GB promotion are then proposed. These processes will lead to Chapters 7 and 8. Conclusions and limitations are drawn after this process.

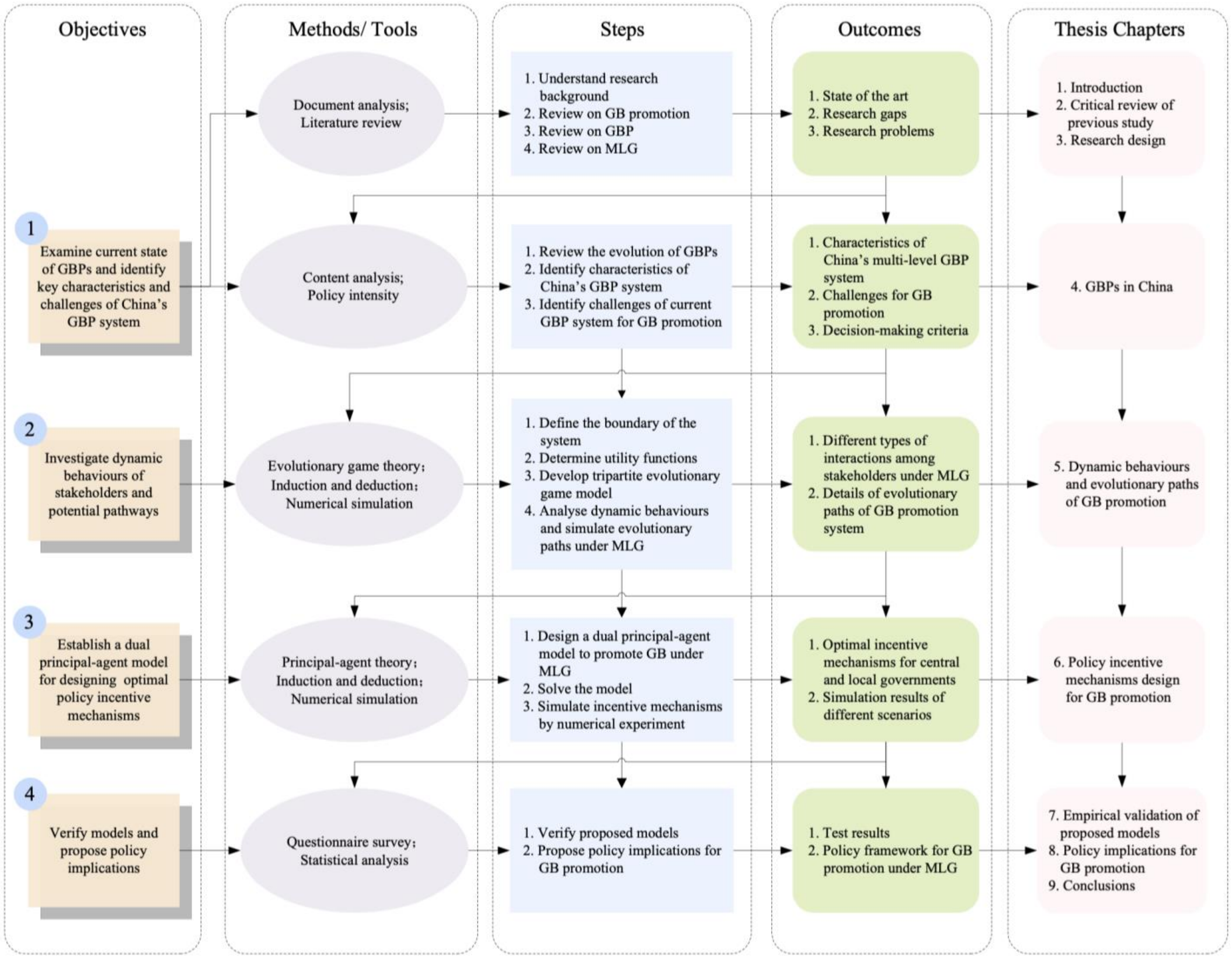

Figure 1.1 Overview of the research process.

1.5 Significance of Research

This study holds significant value for both academic community and policy practitioners involved in GB promotion within China's MLG framework. This study addresses a critical gap in understanding the complex interplay between central and local governments and other stakeholders in GB promotion, offering fresh insights into how policy incentives, governance structures, and behavioural dynamics interact in this context.

The significance of this study lies in its potential to inform policy decisions that can enhance the effectiveness of GB strategies in China. By examining the evolution and characteristics of GBPs, this study provides valuable information that can guide the refinement of policy frameworks. Understanding the challenges within the current GBP system can help policymakers at both the central and local levels design more targeted, context-specific, and impactful policies that address these challenges.

Moreover, the use of theoretical models, such as the tripartite evolutionary game model and the dual principal-agent model, allows for a deeper understanding of stakeholder behaviours under conditions of information asymmetry and competing interests. This study provides a more nuanced view of how incentives can be structured to align the actions of various actors, thus fostering cooperation and improving the efficiency of GB promotion.

Finally, the findings of this study are significant for advancing the broader field of MLG and green policy research, offering new perspectives on governance mechanisms, incentive design, and policy implementation. It provides a solid foundation for future studies in similar governance systems globally, where the relationships between various levels of government and non-state actors play a critical role in achieving sustainable development goals.

1.6 Structure of the Thesis

CHAPTER 1 introduces and highlights the whole research picture, including the research background, scope, overall research aim and specific objectives and significance.

CHAPTER 2 comprehensively reviews the literature on GB promotion, GBP, and MLG to lay the present research's foundation.

CHAPTER 3 introduces the research design and the methods and analytical techniques applied.

CHAPTER 4 comprehensively reviews and analyses the GBPs in China to reveal the evolution of the GBP system and identify the characteristics of this system and critical challenges for GB promotion.

CHAPTER 5 reveals key stakeholders' behavioural mechanisms and evolutionary pathways in GB promotion within China's MLG system. A tripartite evolutionary game model is constructed to analyse the dynamic interactions of key stakeholders—central government, local governments, and developers—under information asymmetry, uncovering decision-making patterns and key factors influencing GB promotion in China's MLG system.

CHAPTER 6 develops a dual principal-agent model to design optimal policy incentive mechanisms for central and local governments under information asymmetry, fostering collaboration among stakeholders and facilitating the adoption of high-quality GBs through scenario-based analysis and numerical simulation.

CHAPTER 7 formulates hypotheses based on the mathematical analysis in Chapters 5 and 6, collects data through surveys, and uses qualitative and quantitative methods to empirically validate the models.

CHAPTER 8 presents policy implications for promoting both the large-scale and high-quality development of GBs based on the policy framework outlined in Chapter 4, the theoretical analyses in Chapters 5 and 6, and the empirical evidence in Chapter 7.

CHAPTER 9 summarises the research findings, highlighting both the theoretical and practical contributions. It also discusses the limitations and outlines potential avenues for future research to guide subsequent investigations.

1.7 Chapter Summary

This chapter provides a comprehensive overview of the research, covering six key aspects: research background, scope, aim and objectives, design, significance and thesis structure.

CHAPTER 2 Literature Review

2.1 Green Building Promotion

2.1.1 Concept of GB

In the global context, since the World Commission on Environment and Development (WCED, 1987) officially proposed sustainable development strategies in 1987, the Rio Declaration on Environment and Development and Agenda 21 (McCammon, 1992), which included the promotion of sustainable human settlement development, was first proposed at the United Nations Conference on Environment and Development (UNCED) in 1992. This has embodied the concept of sustainable development in the Architecture, Engineering and Construction (AEC) sector and is also the concrete realisation of GB (UN, 1992).

According to the International Council for Research and Innovation in Building and Construction (CIB, 1999), sustainable construction is "*a holistic process starting with the extraction of raw materials, continuing with the planning, design, and construction of buildings, and ending with their demolition and management of the resultant waste*". To achieve a healthy built environment, sustainable construction embraces extra criteria that prioritise minimising resource consumption and environmental procedures (Kibert, 1994). Globally speaking, this paradigm shift in the AEC industry has social, cultural and environmental implications (CIB, 1999).

Henceforth, the AEC industry's paradigm shift has gradually increased the requirement for GB development. GBs have become the main direction of the global AEC industry development (Y. Shi & Liu, 2019). The definition of GB has not yet achieved international consensus because of distinctive conditions, such as culture and traditions, economic development level, per capita resources and geographic location (Y. Shi & Liu, 2019; Y. Zhang et al., 2019). According to the United States Environmental Protection Agency, GBs are those that "*are resource-efficient and environmentally conscious throughout the entire life cycle, from site* *selection to design, construction, operation, maintenance and deconstruction*" (USEPA, 2016). A sustainable building in Japan is one that is designed "*to save energy and resources, recycle materials and minimise the emission of toxic substances throughout its life cycle, to harmonise with the local climate, traditions, culture and the surrounding environment, and to be able to sustain and improve the quality of human life while maintaining the capacity of the ecosystem at the local and global levels*", as defined by the Architectural Institute of Japan (Japan, 2022). If a building in Singapore complies with the Green Mark Scheme's requirements, it is deemed green (GREEN MARK 2021, 2021). The scheme requires the building to be energy- and water-efficient, environmentally sustainable, healthy, resilient and maintainable. A commonly accepted definition in the United Kingdom (UK) and European Union (EU) is that GB helps to preserve the environment in some manner while also considering the occupants' welfare, both in terms of living space and air quality (Y. Zhang et al., 2019). China has defined GB as a high-quality building that stresses resource conservation, environmental protection, pollution reduction and providing people with healthy, suitable and efficient living room to achieve harmonious coexistence between humans and nature throughout the life cycle (Ministry of Housing and Urban-Rural Development, 2020).

Despite multiple interpretations of GB, the major themes of GB are (1) climate action, (2) health and well-being and (3) resources and circularity (GREEN MARK 2021, 2021). These themes serve as a benchmark for the development of GB all over the world. Based on Samer (2013), Table 2.1 summarises comparisons between GBs and TBs, where GBs aim at achieving proven sustainable performance, including energy performance, indoor environment, carbon reduction and sustainable materials.

Table 2.1 Comparisons between TBs and GBs

Type	Traditional buildings	Green buildings
Emissions	High	Low
Energy Efficient	Low	High
Indoor Environment Quality	Good	Very good
Building Materials	Not environmental friendly	Environmental friendly
Waste Management	Efficient	Highly efficient
Water Efficiency	Low	High
Project Practices	Normal	Sophisticated
Feasibility	Threshold	>5% than Threshold

2.1.2 Drivers and barriers to GB promotion

A driver is a factor that drives something to happen or develop, whereas a barrier is a factor that prevents the project from achieving its goals (Ahmad et al., 2019). Accordingly, in the context of GB promotion, drivers are the factors that enforce, encourage or promote GB development, whereas barriers are the factors that hinder GB development.

Extensive research has been conducted to investigate the barriers and drivers associated with GBs. Meryman & Silman (2004) summarised the three main barriers to sustainable development: policy, technical and economic factors. Based on that, J. Yang & Yang (2015) divided Australia's barriers to sustainable housing into technical and design, economic, socio-cultural and institutional factors, identifying economic factors as the most essential. Similar barriers were identified in the United States (Mulligan et al., 2014) and Singapore (Ofori &

Kien, 2004), where costs of GB were the most frequently reported barrier. Besides GB costs, information availability was recognised as a critical barrier in China to fostering green construction (Q. Shi et al., 2013). Similarly, Bond (2011) showed that cost and lacking information were key barriers to GB in New Zealand and Australia. Regarding this, the government's role and actions are highlighted as a significant factor. "Legislation" was identified as a major driver for GBs in Singapore (Pheng Low et al., 2014), Hong Kong (Gou et al., 2013) and the UK (L. Wang et al., 2014). Meanwhile, the government's tax reduction incentives would be a crucial policy to promote sustainability in Chile (Serpell et al., 2013). Darko et al. (2018) investigated the factors in Ghana based on responses from 43 related professional practitioners. The results underscore the positive impact of government regulations and incentives, as well as R&D support. Sakr et al. (2011) found the government's crucial enabling role in Egypt's eco-industrial park, and it is suggested to strengthen law compliance and enforcement. Furthermore, W. Zhu et al. (2023) noted that the government's incentive policies are among the primary factors influencing the high-quality development of GBs.

In practical case analysis, Richardson & Lynes (2007) performed several in-depth semi-structured interviews at the University of Waterloo (UW) based on the UW's current practices. The result revealed that most teaching and administrative staff worry about GBs' maintenance costs and focus on the workspace and buildings' comfort rather than sustainability. A similar situation happened in studying two traditional engineering schools/colleges in Sao Paulo. Kasai & Jabbour (2014) also investigated the practitioner and manager in the two GB projects. The survey revealed that the main problems are the high initial investment and maintenance costs and the lack of related GB certificate standards and professional engineers.

To comprehensively understand the influence factors, Olubunmi et al. (2016) reviewed 65 GB incentives-related papers. They classified the incentives into two types: external incentives (force project stakeholders or other potential beneficiaries to make choices) and internal incentives (manifested as an appeal to the goodwill of stakeholders). Besides, the study proposed that non-financial incentives could encourage owners to enter GBs more than financial incentives and emphasised that cooperation between the government and private sector is essential to promoting GB. Meanwhile, Darko et al. (2017b) focused on the driving factors of GB and extracted 64 factors from 42 empirical studies. The proposed framework includes five main categories: external drivers, enterprise-level drivers, property-level drivers, project-level drivers and individual-level drivers. They concluded that government regulations and policies are critical in GB promotion and suggested that countries with GB regulations should regularly look for opportunities to improve their effectiveness. L. Chen, Chan, Owusu, et al. (2022) collected and reviewed 40 critical success factors of GB and subsequently used meta-analysis to quantify the priority of these factors. The result found that studies emphasised the economics of GBs, and comprehensive codes and standards are high-frequency factors. The result also pointed out the critical role of government in GB promotion. Recently, Olabi et al. (2025) explored how GBs contribute to achieving the UN Sustainable Development Goals by promoting renewable energy integration, enhancing sustainability, and addressing design and retrofitting challenges. Overall, among these studies, the high cost of GB and information availability are the most recognised problems hindering the development of GB. Given this, the government, as the main driver for GB promotion, has taken steps to provide incentives and regulation policies worldwide. Specifically, the government provide incentives such as direct grants and tax incentives to shorten the payback period of GBs (Olubunmi et al., 2016). Besides, accelerated licensing or technical assistance saves the owner's time by reducing risks and process problems (C. Choi, 2009). When the time is significantly reduced, the project cost for the owner will be indirectly reduced. Moreover, the central government introduced GB in the national development strategy, issuing regulations and directional policies for promotion

(Gou, 2020; Y. Liu et al., 2019). However, why are GBs still suffering from these problems, especially in China (Q. Feng et al., 2020)? The lack of efficient policies related to GB might be responsible for that. Schemes designated by the government cannot play a role. Therefore, to formulate efficient policies for the government to conquer the barriers, it is essential to systematically understand China's GBP and identify the main challenges to policy development for GB promotion.

2.2 Green Building Policies

As a regulatory tool of the government, policies aim to guide events towards more rational and clearly defined outcomes (Wuni et al., 2019). In the paradigm shift towards GBs, the lack of effective GBPs has been identified as a key barrier to their development (Darko & Chan, 2017). Globally, the critical role of policy in promoting GBs has been widely recognised and emphasised (Darko et al., 2018; Darko & Chan, 2018; Y. Li et al., 2021; Williams & Dair, 2007). Consequently, scholars have continued to advance research on GBPs, seeking to facilitate the design of effective policies across different regions of the world (Wuni et al., 2019).

2.2.1 Analysis of GBP content

Analysing policy content itself helps to understand the characteristics of the policy system and identify existing issues to advance policy improvement. Such research generally involves three major steps: (1) identifying relevant policy documents, (2) describing and analysing the policies and (3) discussing policy-related challenges (Chang et al., 2016). Current studies on the content analysis of GBPs can be divided into static and dynamic analyses, with dynamic analysis placing greater emphasis on policy evolution.

From a static perspective, some scholars have conducted comprehensive reviews of GBPs. For example, Franco et al. (2021) compared and analysed GBPs in both developed and developing countries, critically examining the potential impacts in similar sectors within Metro Manila based on experiences from different cities. Y. Shen & Faure (2021) investigated legal and policy tools that promote GBs, using China's GBPs as a case study. Numerous scholars have concentrated on analysing specific types of GBPs, particularly focusing on distinct policy tools or objects. Regarding policy tools, research primarily concentrates on technical and financial incentive policies. Regarding technical policies, Iwaro & Mwasha (2010) analysed the status of GB standards in 60 developing countries and proposed potential solutions to address regulatory barriers in building energy management. Potbhare et al. (2009) reviewed GB guidelines in developed and developing countries, summarising the characteristics of guidelines in developed nations and analysing their influence on similar guidelines in India. In China, Geng et al. (2012) reviewed the development of national GB evaluation standards, comparing them with international standards and identifying future challenges, such as the lack of climate adaptation indicators, regional indicators, quantitative metrics, high certification costs, and insufficient application of innovative green technologies. Ye et al. (2015) expanded the data sample to include provincial-level policies, conducting a comprehensive review of over 70 national and provincial GB standards. They examined the background and current status of GB standards and proposed a three-tiered system comprising basic, general, and specialised standards. J. Wang et al. (2017) focused on local-level policies, reviewing the distribution, framework, and content of existing local GB design standards. By comparing these standards with region-specific conditions (e.g., climate, resources, economy and culture), they found that economic factors are rarely considered. Implementing sustainable construction design standards that align with different economic stages can effectively promote GB adoption. Research on financial and tax incentives for GBs is relatively extensive across countries. For instance, Shazmin et al. (2016) examined global incentive policies aimed at promoting GB development at the local level. They concluded that incentives have been effective in encouraging GB adoption. Bertoldi et al. (2021) reviewed various financial tools within the EU that promote energy-efficient renovations, exploring their adoption, characteristics, benefits, challenges and applicability to residential buildings. Rana et al. (2021) provided a comprehensive review of financial and tax incentives for GBs at different levels in Canada, identifying variations in the number, type and location of incentives, with utility-based incentives being the most common across all provinces. In China, Xu Z. (2016) analysed provincial-level GB incentives, examining their general characteristics and differences across provinces, and proposed recommendations for optimising the "13th Five-Year Plan" incentive policies. Cai Q. (2018) reviewed and summarised Singapore's GB incentives, providing recommendations for policy development in Fujian Province, China. In terms of specific policy objects, there is a substantial focus on policies related to green retrofitting. For example, Sebi et al. (2019) analysed the green retrofitting policies in France, Germany, and the United States, summarising efforts, achievements, challenges, and future directions in these countries.

Dynamic analysis of GBPs provides valuable insights into the evolution and strategic development of these policies (M. Qin et al., 2020), establishing a reliable theoretical and practical foundation for future policy formulation and improvement (Song et al., 2021). In recent years, scholars have increasingly adopted a dynamic perspective in examining GBP development. For instance, Kuo et al. (2016) examined the evolution of smart GBPs in Taiwan, revealing that Taiwan has not yet established a comprehensive policy mechanism to address the carbon emission costs of economic activities or to support the development of a green circular economy. The existing measures are still limited to incentives and mandatory policies. B. Wen et al. (2020) explored the changes and trends of ten different GB rating tools over the past 30 years, analysing the shifts in categories, sub-categories and standards. Results indicated a consistent decline in the weight of environmental categories, while social categories have gained significant importance. Regarding China's GBPs, most scholars have focused on specific policy objects, such as green retrofitting (G. Liu et al., 2020) and green residential buildings (J. Wu & Ying, 2024). By contrast, Z. Wu et al. (2021) conducted an inclusive analysis of all topics related to GBs, collecting 199 national-level policies and examining the evolution of China’s GBP system. Gan et al. (2023) applied a network-based analysis to 129 national GBPs, focusing on policy agencies, objectives and instruments. Their findings highlighted increasing cross-level coordination among agencies, dynamically evolving yet continuous policy objectives and a significant mismatch between policy instruments and objectives. Xiao et al. (2024) further expanded the scope by analysing both central and local GBPs in China using natural language processing, Latent Dirichlet allocation and semantic network analysis framed by policy implementation theory, sustainable development theory and innovation diffusion theory. Their study identified distinct sustainability focuses across policy levels, suggesting improvements such as enhanced guidance, financial incentives, technological support and stakeholder engagement.

While content analysis research on GBPs has become relatively well-established, comprehensive dynamic reviews of policy evolution are still limited. Current knowledge tends to focus on specific policy types (e.g., technical policies), objects (e.g., green retrofitting) or administrative levels (e.g., national policies). However, there is a lack of comparative analysis of policies issued by various levels of government, such as differences in policy structure and intensity and limited insights into policy preferences across these levels. Examining China’s GBPs from historical, holistic and multi-level perspectives could provide a more comprehensive understanding of the policy system’s characteristics and challenges, thereby informing more effective policy design. Accordingly, this study undertakes a dynamic review and analysis of central and local GBPs in China.

2.2.2 Evaluation of GBP effectiveness

With the implementation of GBPs, it is crucial to evaluate whether these policies effectively facilitate GB adoption. Existing research has predominantly assessed policy effectiveness through policy scoring and empirical testing. Due to the inherent subjectivity associated with scoring, studies in this area are relatively scarce. For instance, Q. Shi et al. (2014) introduced a fuzzy impact matrix approach to evaluate the effectiveness of GBPs, applying it to policies enacted during China's "11th Five-Year Plan". The findings demonstrated that some policies are indeed effective in promoting GB development; however, issues such as financial and tax incentives require further refinement to enhance policy outcomes.

To mitigate the influence of subjectivity, many scholars have adopted empirical methods to objectively assess GBP effectiveness. In the United States, Cidell & Cope (2014) observed that municipal-level GBPs are associated with a significant increase in GB projects, showing a strong correlation between the number of policies and ongoing GB initiatives. Lee & Koski (2012) examined GBPs from a MLG perspective, using hierarchical models to reveal that city-level policies are more impactful in promoting GB adoption than state-level initiatives. E. Choi (2010) found that municipal-level regulatory policies are particularly effective in driving GB uptake, whereas incentive-based policies have limited success. Conversely, E. Choi & Miller (2011) concluded that federal-level incentive policies are more effective than regulatory measures. Simons et al. (2009) reported that GBPs, regardless of the government level (federal, state or local), influence the penetration of green commercial buildings, with executive orders expediting GB promotion. Fuerst et al. (2014) analysed market penetration rates of commercial buildings with Leadership in Energy and Environmental Design (LEED) certification across 174 core-based statistical areas in the United States, finding that mandatory LEED certification significantly increased market penetration, while other policies had negligible effects. Adekanye et al. (2020) explored the relationship between local and federal policies and the growth of commercial GB retrofits using panel data models with location and year effects. Their findings indicated that policy effectiveness is contingent on the type of policy and the federal policy environment, with mandates and density bonuses proving to be effective tools.

In Singapore, D. Zhang et al. (2024) examined the impact of minimum GB standards and found that the mandate led to an increase in entry-level, low-performing GBs, while the rise in high-performing, certified GBs was modest, suggesting that mandatory regulations encourage broader GB adoption but do not adequately promote higher performance.

The effectiveness of GBPs varies significantly across different political and economic contexts. Numerous studies have examined GBPs within China's unique political framework. C. He et al. (2021) utilised a panel regression model to demonstrate that both national and local policies drive the overall diffusion of green housing, though effectiveness differs by GB grade. Specifically, national and local policies effectively promoted 1-star green housing but struggled to advance 3-star green housing. For 2-star green housing, national policies were impactful, while local policies had minimal influence. Zou et al. (2017) refined the categorisation of provincial policies, finding that local economic conditions and subsidy-based incentives explained the increase in GB projects. However, local green standards and GB councils did not significantly correlate with provincial GB concentration, suggesting the need for stronger policy enforcement. Similarly, L. Zhang et al. (2018a) analysed the effects of various provincial policies on GB promotion, noting that subsidies targeting GB developers could somewhat stimulate higher-grade green housing. Kong & He (2021) evaluated the influence of provincial supply-side and demand-side incentives on GB technological innovation, discovering that supply-side policies were particularly effective, while demand-side incentives had a moderate impact. Song et al. (2021) further assessed city-level GBPs, concluding that both regulatory and incentive-based measures promote GB adoption, with regulatory approaches having a greater influence on GB development.

Overall, empirical studies indicate that well-designed and implemented policies positively impact GB promotion (Cidell & Cope, 2014). Introducing GBPs within a jurisdiction is expected to stimulate GB development (Kaza et al., 2013). Nevertheless, these studies also highlight disparities in the effectiveness of policies at various governmental levels and of different types. For instance, while incentive policies can successfully promote lower-grade GBs, they are less effective in fostering the adoption of higher-grade GBs. This underscores the necessity for governments to refine and enhance the implementation of relevant policies.

2.3 Stakeholders' Behaviours in Green Building Promotion

Research on stakeholder behaviour seeks to understand the factors influencing actions and their interrelations, aiming to deepen insight into decision-making processes among key actors (Kim et al., 2019; Medal & Kim, 2017). Such insights can inform strategies to guide these behaviours effectively. In the context of GB promotion, stakeholder behaviour studies are broadly divided into behavioural intention surveys and behavioural game models. The former relies on empirical methods such as questionnaires, case studies and experiments. For example, focusing on a single stakeholder group, S. Yang et al. (2019) employed a questionnaire survey and structural equation modelling grounded in the theory of planned behaviour to examine the determinants of developers' green procurement behaviour. The findings suggested that developers with a proactive attitude towards green procurement perceived enhanced support from both internal and external environments, exhibited stronger control over resources, and demonstrated greater responsiveness to emergent challenges, thereby increasing their propensity to implement green procurement initiatives. Chau et al. (2010) investigated the influence of end-users on GB development behaviour through a discrete choice experiment. Their study revealed that residents with prior GB experience exhibited differentiated preferences and a higher willingness to pay for improvements in environmental performance, placing particular emphasis on energy efficiency relative to other aspects, such as indoor noise reduction, landscape area, water usage and air quality. For studies encompassing multiple stakeholder groups, Tunji-Olayeni et al. (2023) evaluated behavioural factors affecting professionals' willingness to adopt green construction practices through the lens of the theory of planned behaviour. Results indicated that both attitude and perceived behavioural control exerted significant influence on GB adoption intentions. Ofek & Portnov (2020) explored the impact of stakeholder knowledge regarding GB benefits on the acceptance of price premiums for GBs among developers, architects and consumers. Findings indicated that increased awareness of GB benefits had heterogeneous effects across stakeholder groups; specifically, developers' acceptance of GB price premiums was inversely associated with their level of knowledge regarding GB advantages.

Behavioural intention surveys, while valuable in elucidating individual behavioural mechanisms to some extent, often overlook the interdependent influences among different stakeholders and lack comprehensive insights into governmental intentions. In contrast, behavioural game models have expanded the understanding of stakeholder interactions and provided a deeper analysis of government behaviour (K. Fan & Hui, 2020; X. Yang et al., 2019). Game theory offers a micro-level analysis of interactions among stakeholders, employing mathematical and logical approaches to reveal underlying market mechanisms, thereby providing a rational basis for policy decisions (Q. K. Qian et al., 2015). Depending on the assumptions about participants, behavioural game models can be categorised as fully rational or boundedly rational. Fully rational models assume that participants have complete access to information and can always make utility-maximising choices through rational deductions, regardless of complexity. Bounded rationality, by contrast, accounts for cognitive limitations and incomplete information, making this approach more reflective of real-world contexts (J. Liu et al., 2022).

Under the assumption of full rationality, Cohen et al. (2017) utilised the classic prisoner's dilemma model to analyse the current landscape of GB development in Israel. Their study focused on three primary stakeholders—government, developers and consumers—and identified obstacles impeding the expansion and advancement of GBs, proposing a strategic framework to address these barriers. The model concluded that government incentives could foster the widespread adoption of higher-standard GBs without imposing significant fiscal burdens. As a result, the government could secure corporate support and public approval at a relatively low cost, steering the market towards a new equilibrium that maximises social welfare. In a subsequent study, Cohen et al. (2019) refined the model by including additional stakeholders—namely, the Israeli government, municipal authorities, developers, regulatory bodies and consumers (apartment buyers). The results highlighted a shortage of environmental expertise within national and local governments, which limited oversight and enforcement even when violations were detected. Moreover, the limited governmental commitment to GB subsidies further hindered the growth of high-standard (two-star and above) GBs. Other scholars have examined GB promotion in different contexts using similar approaches. For example, Liang et al. (2016) employed a non-cooperative game model to analyse the behaviours of building owners and tenants in green retrofitting projects, identifying incentive misalignments, complex coordination requirements, and the uncertainties inherent in green retrofitting as factors discouraging participation from key decision-makers. W. He, Zhang, Li, et al. (2024) addressed betrayal in GB supply chains using a quantum game model involving developers and contractors. By extending a classical non-zero-sum game to a quantum strategy space, they found that quantum entanglement reduces betrayal risks, as full effort remains unaffected by partial effort under maximum entanglement. They proposed an entanglement treaty to stabilise cooperation, offering practical insights for enhancing commitment to GB projects. He et al. (2024) expanded this approach by introducing additional stakeholders, specifically the building materials supplier, to address a multi-player context. This three-party quantum game model revealed that entanglement significantly increases developers' willingness to invest, and the entanglement treaty promotes cooperation among all parties, offering a more comprehensive framework for collaboration in sustainable GB initiatives.

While these studies contribute valuable insights, their reliance on full rationality assumptions limits applicability in real-world GB promotion. Full rationality disregards psychological and social factors such as cognitive biases and social influences, as well as the incomplete information and bounded rationality characteristic of real decision-makers whose cognitive capacities and resources are finite. Consequently, models based on full rationality assumptions often lack practical relevance and fail to capture the complexities of actual GB promotion dynamics. Recognising these limitations, an increasing number of scholars have adopted bounded rationality assumptions and employed evolutionary game theory to analyse stakeholder behaviours in GB promotion (Y. Li et al., 2022). Evolutionary game theory, diverging from the traditional assumption of full rationality, considers information asymmetries and examines behavioural interactions and pathways from a dynamic perspective (W. Fan et al., 2021). In recent years, evolutionary games have become a focal approach for studying stakeholder behaviour in GB promotion. Wang J. & Qin (2013) were among the early researchers to apply evolutionary game theory to the study of GB promotion, analysing the development behaviours of various developer groups. Their study revealed that factors such as excess returns and discount factors in GB projects are critical determinants influencing developers' engagement in GB development. Wang B. (2018) examined the interactions between developers and construction units, incorporating government subsidies as an exogenous factor. They found that subsidies reinforce the GB orientation of both parties. R. Zhao et al. (2024) modelled the coevolution of developers, construction enterprises and innovation consortium in GB technology innovation. Using a tripartite evolutionary game approach, they found that government subsidies enhance strategic interdependence, driving the GB technology ecosystem towards mutualistic symbiosis. However, many of these studies have not fully considered the government's role in GB promotion. Acknowledging the crucial role of government in GB development, a growing number of scholars (K. Fan & Hui, 2020;

Y. Gao et al., 2022; Y. Lin et al., 2024; X. Lu et al., 2025; Meng et al., 2021) have introduced government actors into evolutionary game models, establishing two-party models to examine interactions between the government authorities and developers, who are the primary decision-makers in GB promotion. With further advancements in evolutionary game theory, researchers (Ai et al., 2024; H. Li et al., 2023; W. Lu et al., 2022; Qiao et al., 2022; Y. Zhao et al., 2024) have increasingly incorporated demand-side actors, leading to three-party models that analyse interactions among government, suppliers and consumers. These studies offer a multi-dimensional perspective on GB promotion, enhancing understanding of strategic adaptations and behavioural mechanisms.

While evolutionary game theory has advanced considerably in analysing bounded rationality-based behaviours among GB stakeholders, existing studies often simplify the government as a single entity within game models, overlooking the MLG structure in China and the varied interests across governmental tiers. This simplification constrains the explanatory power of these models, limiting their ability to accurately capture the complexities of stakeholder behaviour within China's MLG system for GB promotion.

2.4 Incentive Mechanism Design for Green Building Promotion

The design of incentive mechanisms is fundamental to advancing GB initiatives, and game theory has emerged as a pivotal tool for examining and structuring such mechanisms. Given that stakeholders in the GB sector, such as developers, contractors and policymakers, are driven by divergent interests, Huo & Yu (2017) suggested that game theory can elucidate the equilibrium points in stakeholder interactions, thereby enabling the design of incentive mechanisms that promote GB adoption effectively.

Scholars have approached incentive mechanism design from two main perspectives: scenarios of information symmetry and those of information asymmetry, offering strategic recommendations tailored to varying market conditions. In scenarios where information is assumed to be symmetric, game models have been developed to align stakeholders' interests towards sustainable outcomes. For example, W. Jiang & Wu (2019) utilised the Stackelberg game model to craft an incentive structure where developers, acting as leaders, can motivate contractors to enhance their GB efforts. Their findings indicated that such incentives reduce developers' costs while simultaneously boosting contractors' profitability, underscoring the potential of well-structured incentive mechanisms to harmonise interests within the supply chain. Government-focused incentive mechanisms dominate the literature, with various studies providing insights into optimal policy design. Jin Z. et al. (2010) modelled a complete-information dynamic game between the central government and developers to explore economic incentives. They advocated a "carrot and stick" approach, suggesting that combining rewards and penalties can effectively stimulate GB efforts. L. He & Chen (2021) adopted a two-stage game model involving developers, consumers, and government, revealing that consumer-targeted subsidies yield better results than developer subsidies, highlighting the importance of targeting incentives appropriately. Yin & Li (2018) further extended this by examining policy design for the transfer of GB technology from research institutions to construction firms. Their findings suggested that government subsidies provide a robust, long-term incentive for technology transfer, which is essential for sustained GB development. Bian et al. (2021) applied real option theory to assess public building energy-saving retrofit projects, concluding that subsidies should be differentiated based on the specific retrofit strategies employed, as this increases policy effectiveness.

However, in real-world applications, information asymmetry between stakeholders presents a significant challenge (J. Li et al., 2019; Xia & Niu, 2020). Governments often struggle to fully understand market dynamics and stakeholder motivations when designing GBPs (Nguyen et al., 2017; L. Zhang et al., 2018b). To address this, several studies have focused on incentive mechanisms under information asymmetry, aiming to develop policy solutions that account for hidden information and strategic behaviour by stakeholders. W. Chen & Li (2021) constructed a principal-agent model to address situations where manufacturers hold private information regarding production costs and effort levels. Their model proposed an optimal government policy mechanism combining subsidies and inspections, ensuring that manufacturers disclose accurate information and act in alignment with policy objectives. W. Chen & Hong (2015) explored scenarios where developers' preferences for GB standards are private and subject to uncertainty. They developed subsidy models under both symmetric and asymmetric information conditions, finding that reducing information asymmetry can effectively expand GB adoption and lower unit subsidies, thereby achieving greater policy impact. Cai D. et al. (2023) focused on policy incentive mechanisms in GB procurement auctions, designing reward-penalty mechanisms based on bidders' private cost information to improve the designs' greenness. They concluded that subsidising bidding firms is superior to subsidising tendering firms. Rong et al. (2022) analysed adverse selection and moral hazard issues in companies' disclosure of green innovation efforts. Using a dynamic incentive model based on the principal-agent framework, they demonstrated that under optimal incentive structures, firms are motivated to sustain green efforts and disclose innovations transparently, aligning corporate actions with public policy goals.

These studies establish a theoretical foundation for incentive mechanism design under information asymmetry. However, these models generally simplify the government's role to a single entity, overlooking the complexities inherent in MLG systems, particularly in decentralised frameworks. Fiscal decentralisation often leads to conflicts of interest and information asymmetry between central and local governments, resulting in policy failures during the transmission of policies across different levels (Qiu, 2021). Although some studies (Li Y. & Jiang, 2022; Zhao C. et al., 2018) have attempted to model these inter-governmental dynamics to achieve coherent policy outcomes, most focus on broader economic development rather than sector-specific policies for GBs. Only X. Yang et al. (2021) proposed a dual-objective incentive mechanism targeting both economic growth and environmental improvement. However, their model, aimed at macro-level environmental policy, lacks the specificity required for the unique challenges of GB promotion, limiting its practical applicability for this domain.

2.5 Multi-Level Governance

2.5.1 The concept of MLG

"*Multi-level governance has emerged as a conceptual approach to studying the development, implementation, effectiveness and accountability of policies. It steps away from the assumptions that national government is the dominant policy-making unit and that policy-making occurs within a nested hierarchical set of government layers (International, national, regional, sub-regional, local)*" (Marsden & Rye, 2010).

As a theoretical approach, this concept emerged in Europe around the 1990s to describe the existence of political authority not only at the level of national governments but also in local units and European institutions (Marks, 1993). This does not imply that regional or supranational organisations are taking the place of European nation-states (Rüffin, 2020). Rather, leading researchers of MLG recognise the continuing authority of member states but pay more attention to the interaction among nation-states, regions and committees (Schakel et al., 2015).

The key concept in MLG is the differentiation between two or more levels. These levels refer to "*political-territorial, administrative units with clear vertical hierarchies or horizontal coordination*" (Brunnengräber & Walk, 2007). Vertical interaction is concerned with relations among multiple tiers of government (national, regional, local), referring to Type I MLG (Liesbet & Gary, 2003; Pahl-Wostl, 2009). This type of interaction could occur in three ways: (1) top-down, where national frameworks affect local action; (2) bottom-up, where local initiatives affect national action; (3) reciprocal (Corfee-Morlot et al., 2009). Type II MLG concerns the distribution of authority over various state and non-state actors. Regarding this type, horizontal coordination could bridge the divides between state and non-state actors (Glasbergen, 2010; Liesbet & Gary, 2003), between different policy areas or sectors (Corfee-Morlot et al., 2009) or between local authorities (Betsill & Bulkeley, 2006).

2.5.2 MLG in environmental domains

Environmental governance is a popular policy field and represents "*the second most-studied policy in relation to MLG*" (Piattoni, 2010). "*The expansion and paradigm shifts in the development of environmental policies development have been intrinsically linked to the development of MLG arrangements*" (Wälti, 2010). To deal with the high complexity of long-term environmental challenges and overcome the limitations of central leadership and local fragmented decentralisation, Underdal (2010) suggested a system of MLG–sufficiently decentralised to motivate local initiatives while simultaneously capable of establishing networks to promote the diffusion of best practice and strengthen the ability for collective action across scales.

According to politics of scale, environmental decisions are "*created, constructed, regulated and contested, between, across and among scales through networking*" (Bulkeley, 2005). The emergence of environmental regime complexes (Abbott, 2012) illustrated how dynamic interactions between formal and informal actors increasingly shape governance (Rosenau, 2021). Horizontally, knowledge flows and exchanges among different regions and actors are multifaceted and are further facilitated by environmental movements (Ehnert et al., 2018; Geys & Konrad, 2010; Lee & Koski, 2015). Although they might not necessarily affect environmental policy decisions, these activities are crucial for local initiatives because they offer motivation by exchanging ideas, knowledge and experiences (Lee & Koski, 2015). Vertically, the multiple layers of strategies and activities of state and non-state actors are captured by the concept of “two-level games” (Putnam, 1988), which were later extended to “multi-level games” (Mayer, 2010). It captures how state and non-state actors attempt to overcome barriers at their own governance levels by strategically exploiting the negotiation process at other levels. For example, to overcome domestic resistance to sustainability, domestic actors can make reference to agreements reached through international negotiations (e.g., the Sustainable Development Goals established by the UN) (Ehnert et al., 2018). In this sense, actors are able to move across multiple levels of government.

Regarding MLG in environmental domains, researchers in diverse fields have applied MLG theory to explain the realisation of climate change adaptation action and natural resources management in different countries, identifying the drivers and challenges related to environmental objectives. For instance, Daniell et al. (2014) described the behind-the-scenes innovation uptake struggles in water cycle management across MLG systems in Australia, China and Bulgaria and suggested having “champions” at least two administrative levels in a coalition could boost innovation uptake. Sun & Baker (2021) illustrated China’s low-carbon governance from the MLG perspective and demonstrated that MLG innovations across administrative and territorial boundaries are essential for sharing ideas, knowledge and experiences in Hongqiao. Smucker et al. (2020) examined MLG practices of climate change adaptation, land restoration and disaster risk reduction in Kenya, highlighting certain features of convergence among these agendas. Instead of through formal mechanisms of law-enforced policy integration, convergence has been made possible by informal working platforms for cross-sectoral collaboration. These platforms united the federal government, local governments and civil society organisations. By examining Brazil and Indonesia’s cross-level interactions in climate change mitigation and adaptation policy processes, Di Gregorio et al. (2019) discovered that power imbalances across governance levels and powerful communities operating predominantly at the national level hinder cross-level interactions. Based on investigating the relationships among power, MLG and renewable energy policy implementation in the Philippines, Marquardt (2017) highlighted the decentralisation failure caused by corruption and clientelism and implementation barriers caused by powerful local authorities, conflicting regulations, vague responsibilities, ignorance of national intentions and missing consultations. Yang et al. (2025) proposed an integrated decision-making framework that couples a multilevel dynamic game with robust multi-objective optimization in sustainable development planning. The approach aims to address the complexities and uncertainties inherent in environmental and economic systems, providing a more resilient and adaptive planning methodology. Komninos & Panori (2025) examined the European Union's strategy for achieving smart, carbon-neutral development through the EU Missions framework. Using Thessaloniki's Net Zero Action Plan as a case study, they highlighted the importance of MLG and the convolution approach in managing the complexities of climate change mitigation and adaptation. The study underscores the need for integrated policies that bridge theoretical concepts with practical implementation. Overall, prior studies recognise that multiple levels of governance affect one another in different countries and highlight the importance of effective MLG in achieving ambitious environmental goals.

2.5.3 China's MLG system

Different from other countries, China is the largest unitary state with one party in the world, providing an intriguing context for exploring the multiple levels of governance (M. Schreurs, 2017). The concept of MLG has been applied to the Chinese context previously (Brueck et al., 2024; K. Chen et al., 2025; Cheng & Zhang, 2024; Z. Huang et al., 2015; Kuhn, 2016; L. Liu et al., 2012; X. Liu et al., 2024; Ma, 2024; Ren et al., 2024; M. Schreurs, 2017; M. A. Schreurs, 2010; J. Zhang & Mora, 2023; M. Zhang et al., 2024; X. Zhang et al., 2024), with a primary focus on vertical hierarchies. Typically, China's administrative units are organised in a multi-tiered system with five formal levels of government: central, provincial, municipal, county, and township (X. Huang et al., 2016). All government levels below the central government are collectively referred to as local governments (Xu Y. & Gao, 2005). The provincial level includes 23 provinces, 5 autonomous regions, 4 provincial-level municipalities and 2 administrative regions (CPGOPRC, 2022). Ruled by the Communist Party, policies determined centrally are expected to be implemented by sub-national governments (M. Schreurs, 2017). Prior to 1980, governance in China had been predominantly top-down, with local administrations merely responsible for carrying out central mandates. During that period, local governments obtained the fiscal spending authority stipulated by the central government under the fiscal contracting system (Z. Huang et al., 2015). With the launch of the open door policy and new tax sharing system (TSS) in 1994, even though the central government has maintained its dominant role in governance, decentralisation of administrative and economic from the central to localities has profoundly changed the local governments' behaviours and central-local relations (Canfei & Shengjun, 2007). Since then, local governments have been primarily responsible for the urban and economic development in their jurisdictions, gaining momentum in the process of reshaping the country (Y. Qian & Weingast, 1996; D. Y.-R. Yang & Wang, 2008; J. Zhu, 1999). Meanwhile, the subordination of provincial, municipal, county and township administrations in authority is determined by the top-down vertical connection. This results in the formation of a deconcentrated governance model, which is characterised by layered intergovernmental incentives and political pressure in vertical governance sparked by persistent and locally entrenched demands.

China's environmental governance is still primarily based on command-and-control regulation, inherited from China's prior planned economy and hierarchical political structure (Carter & Mol, 2013; Palmer, 1998). Since the beginning of economic reform, China's fiscal authority has been greatly decentralised (Y. Xu, 2011). Local governments enjoy greater power to direct their financial resources, such as investing in developing economies or protecting the environment (J. Jin & Zou, 2005). Therefore, under the “yardstick competition” among localities created by the central government, judging their performance based on economic performance to promote their career (X. Zhang, 2006), local cadres have a strong incentive to grow the economy rather than protect the environment (J. Jin & Zou, 2005). This has resulted in local governments implementing short-term local policies for economic reasons in the past decades, hindering long-term sustainable development (Mol & Carter, 2006). Recognising this, the Central Committee of the Communist Party of China introduced new requirements for the promotion of local cadres, emphasising that environmental protection is a crucial criterion for evaluating and promoting local cadres (CPC, 2006). In the meantime, to ensure honest reports of pollution reduction records, the Ministry of Environmental Protection conducted a twice-per-year inspection program for provinces. Such a scheme links implementations of environmental policies to the local cadres’ evaluation and is regarded as one of the most important factors in achieving pollution reduction (Cao et al., 2009).

While placing emphasis on environmental protection, China’s central government nevertheless demands strong economic performance and restricts local borrowing (M. Liu et al., 2022). Due to the pressure of the central government’s environmental protection assessment, a non-cooperative game interaction between central and local governments is common (Chu et al., 2019), and collusion between local firms and governments is rather widespread (X. Yang et al., 2021). Meanwhile, conflicting priorities of sub-national governments and information asymmetry across multiple levels of governments lead to the inefficient implementation of environmental and energy policies (T. Hong et al., 2019; M. Schreurs, 2017), reflecting China’s fragmented MLG landscape. Without adequate policy from upper-level governments, the local government would prioritise economic and political goals.

In light of this, researchers across a range of disciplines attempted to offer some references for China’s administrations to develop their environmental policy. For instance, Gao et al. (2019)

analysed the interaction between central and local governments in the Eastern Route of South-to-North Water Transfer Project based on an evolutionary game model. They found that punishment on downstream governments could effectively affect the strategies of governments across all levels. X. Yang et al. (2021) developed a two-level principal-agent model to explore how the central government, local governments and companies interact in environmental governance. They suggested merging principal-agent levels through vertical management. According to a tripartite evolutionary game model, K. Li & Dong (2022) discussed the strategic behaviours of stakeholders in the gasoline vehicles ban process from the MLG perspective. It is suggested that efforts be enhanced to establish clean local governance and support the ban on gasoline vehicles. To promote China's regional synergistic governance of haze pollution, M. Zhang et al. (2019) constructed a three-sided evolutionary game model to analyse the interactions between the central government and two heterogeneous local governments. Results indicated that increasing the reputational damage of the superior government's inaction is a crucial assurance for effective implementation supervision.

Although prior studies have advanced the field of strategic interactions among stakeholders from China's MLG perspective, insights specifically related to the GB field remain limited. The real estate sector functions as a key engine of economic growth and a source of financial assets (Cugurullo, 2018; J. Shen et al., 2020; F. Wu, 2022; Z. Yang et al., 2018). However, it has been alleged that "low-carbon", "eco" and "green" programs have merely been exploited as "greenwashing" in many Chinese localities to facilitate real estate growth in speculative ways (Caprotti, 2014; Caprotti et al., 2015; Miao & Lang, 2015; L. Yu, 2014). There is a trend of the Chinese government paying more and more attention to the development of GB market through the implementation of various policies (X. Yuan & Zuo, 2011). Still, MLG may present a great challenge for governments looking to bring about policy change (M. Schreurs, 2017). In fact, due to information asymmetry and positive externalities, there exist numerous opportunistic behaviours in GB market: on the one hand, collusion between local governments and firms sometimes happens (Fredriksson & Millimet, 2002; Y. Qian & Roland, 1998; H. Wu et al., 2020); on the other hand, some developers even false marketing to gain excess profits and falsely assess greenness to receive subsidies (Qiao et al., 2022). Thus, it is still waiting for efficient policies to promote GB from China's MLG perspective.

2.6 Research Gaps

Gap 1: Insufficient multi-level analysis of GBP evolution and spatial distribution

While considerable research has examined the content, evolution and effectiveness of GBPs, few studies have conducted a comprehensive, multi-level analysis of policies across different tiers of government. Existing research often focuses on policies at either the central or local level or on specific policy types (e.g., technical support), usually employing quantitative analyses at a single level. This segmented approach fails to capture the systemic patterns and spatial characteristics of China's GBP landscape across regions and administrative levels, hampering the development of an integrated framework. A thorough, multi-level examination of policy evolution and spatial distribution is essential to provide a systemic understanding of policy trajectories, challenges and regional disparities, thereby supporting coherent, evidence-based policy formulation, implementation and assessment (B. Zhu et al., 2021). Without such analysis, it is challenging to identify gaps in policy coverage, misalignments between central and local priorities or regional disparities that may hinder effective GB promotion.

Gap 2: Limited understanding of stakeholder interactions within China's MLG framework

Current research on stakeholder behaviour in GB promotion predominantly examines single-tier governance, overlooking the complex interactions that occur within China's MLG framework. In practice, GB promotion involves interconnected actions among diverse stakeholders whose behaviour is influenced by rational decision-making within a multi-level equilibrium. The dynamic between central and local governments, as well as between public and private stakeholders, occurs under conditions of information asymmetry, resulting in varied behavioural responses that impact policy implementation and GB promotion outcomes. The limited exploration of these interaction mechanisms within China's MLG structure restricts the formulation of policies that can effectively coordinate and align stakeholder incentives. A deeper understanding of these behavioural interactions within China's MLG context is crucial to designing policies that foster collaboration, minimise conflicts of interest and ensure alignment with national sustainability goals.

Gap 3: Lacking multi-level incentive mechanisms to address information asymmetry

Information asymmetry between central and local governments complicates effective policy implementation, often leading to unintended policy distortions. Although some studies have explored incentive mechanisms to address information asymmetry in GB promotion, these efforts typically focus on a single level of government, overlooking the central government's strategic design role and the dual principal-agent relationships between government tiers and between government and industry. Consequently, existing incentive mechanisms do not fully address the complexities of China's decentralised governance model, nor do they facilitate the intergovernmental coordination essential for effective GB promotion. Effective GBP incentive mechanisms must account for multi-level interactions and design incentives that align both central and local interests while reducing the risks of adverse selection and moral hazard associated with information asymmetry.

2.7 Chapter Summary

This chapter provides a structured review of literature related to GB promotion, GBPs, stakeholder behaviours, incentive mechanisms and MLG, focusing on China's unique context. This chapter begins by introducing the concept of GBs and identifying drivers and barriers affecting GB adoption. It then examines GBPs, assessing both content and effectiveness in promoting GB initiatives. Stakeholder behaviour and incentive mechanisms are explored to understand how different actors influence GB promotion and how well-designed incentives can align stakeholder actions. MLG is discussed in relation to China's environmental governance system, highlighting challenges such as information asymmetry and conflicting objectives between central and local levels. Finally, research gaps are identified, noting the need for integrated multi-level analyses of GBPs, deeper insights into multi-level stakeholder interactions and advanced incentive mechanisms to support coordinated GB promotion within China's MLG system.

CHAPTER 3 Research Methodology

3.1 Introduction

This chapter outlines the research methods and analysis techniques adopted in this study. First, it provides an overview of the methodology designed to address each research objective. Second, it elaborates on each specific method and analytical technique, demonstrating their suitability and effectiveness.

3.2 The Framework of Methodology

To address the research objectives, the framework of methodology is outlined in Table 3.1, encompassing a summary of the research methods and analytical techniques employed. This framework integrates both qualitative and quantitative approaches.

Table 3.1 Research framework.

Research objectives	Research methods	Analysis techniques
(1) To examine the current state of GBPs and identify the key characteristics and challenges of GBP system in China	1. Document analysis	1. Policy intensity assessment 2. Mixed content analysis 3. Statistical analysis 4. Comparative analysis
(2) To develop a tripartite evolutionary game model and investigate the dynamic behaviours of stakeholders and potential pathways	1. Modelling and simulation 2. Expert interview	1. Evolutionary game theory 2. Sensitivity analysis 3. Comparative analysis

(3) To establish a dual principal-agent model for designing the optimal policy incentive mechanisms	1. Modelling and simulation 2. Expert interview	1. Principal-agent theory 2. Sensitivity analysis 3. Comparative analysis
(4) To empirically verify the proposed models and propose policy implications	1. Questionnaire survey	1. Statistical analysis

3.3 Research Methods

3.3.1 Document analysis

Document analysis aims to solve research problems by examining a variety of recorded information, including academic publications, industry reports and digital or print reports from international organisations (Patton, 1990). It can supplement the information collected through other methods, such as questionnaire surveys and interviews, in certain cases (Babey, 2020). As implied by its name, document analysis, also known as content analysis or existing data analysis, refers to the process of examining factors or trends in already-existing documents (Witkin et al., 1995). Any approach for conducting inferential processes that objectively and methodically analyse and identify references from a theoretical standpoint is referred to as content analysis (Lang, 1971). This research systematically reviews, categorises, integrates and analyses existing research on GB promotion and MLG. The research objectives, which form a solid foundation for the subsequent analyses, are established by identifying and summarising the research gaps and limitations. Moreover, content analysis is a commonly used research method that can convert qualitative text into quantitative data. This method enables researchers to analyse policy content quantitatively, clarify the essence of the current policy and its evolutionary process and improve their cognition of the texts according to these data (Peng & Liu, 2016; Scott, 1955; Weber, 1990). In practice, categorising and coding are crucial for applying content analysis (Stemler, 2019). In this regard, a coding table of "Green Building Policies" is built. Existing achievements and challenges in the current GBP system are explored.

3.3.2 Questionnaire survey

The questionnaire survey is an effective method for conducting empirical research because it allows for the collection of quantitative data without physically interacting with the respondents. Giving respondents a list of options for any single question would enable the collection of standardised data from the respondents. The questionnaire should not contain any unclear or difficult-to-understand language and should be simple to understand and complete (Chisnall, 1993). The advantage of the questionnaire survey is that it can produce a significant amount of quantitative data, which could be used to investigate and synthesise the key findings. The data quality control, however, becomes challenging. In this research, a questionnaire survey is used to get professional feedback on the proposed models. Specifically, on a five-point Likert scale, respondents are invited to score the degree of agreement with the importance of each individual item.

3.3.3 Expert interview

Expert interview is a widely recognised qualitative research method employed to gather in-depth insights from individuals possessing specialised knowledge or experience in a particular domain. These interviews are particularly effective for understanding complex issues, identifying trends or validating theoretical frameworks (Bogner et al., 2009). By focusing on the expertise of key informants, this method enables researchers to capture nuanced perspectives that are often unavailable through other data collection techniques, such as surveys or secondary data analysis.

The key strength of expert interviews is their capacity to generate rich, contextually relevant data. First, they allow researchers to probe deeply into issues that require specialised understanding, enabling a nuanced exploration of processes, challenges and opportunities (Flick, 2014). Second, the method is flexible, as interviews can be structured, semi-structured or unstructured depending on the research objectives and the participant's expertise. This adaptability ensures that the interviews can capture both planned and emergent themes. Third, expert interviews are an excellent means of validating theoretical models or assumptions, as they provide credible insights grounded in the real-world experiences of participants (Monke, 2021).

Conducting expert interviews typically involves a series of carefully planned steps. Researchers first identify and recruit participants whose expertise aligns with the research focus. Selection is often guided by criteria such as professional credentials, academic publications or leadership roles. Once participants are identified, researchers prepare an interview guide featuring open-ended questions that allow for exploratory discussions while maintaining alignment with the study's objectives. Data collection can be conducted in person, over the phone or via digital platforms, ensuring ethical considerations such as informed consent and confidentiality are respected. After data collection, researchers transcribe and analyse the interview content using qualitative methods, such as thematic coding, to extract meaningful patterns and insights (Meuser & Nagel, 2009).

3.3.4 Modelling and simulation

Modelling and simulation involve the development of mathematical or computational models to represent complex systems, processes or phenomena (Birta & Arbez, 2019). This approach allows researchers to study and predict the behaviour of these systems under various conditions without the need for direct experimentation, which may be impractical or costly. By constructing theoretical models, researchers can derive insights into the underlying mechanisms, test hypotheses and explore the implications of different assumptions in a controlled and systematic way.

Modelling often begins with the formulation of a set of equations or algorithms that describe the key variables and their relationships within the system being studied. These models may range from relatively simple, analytical models to more complex, computational models that require numerical methods for solutions. Simulation, on the other hand, refers to the use of computational techniques to solve these models and simulate the behaviour of the system over time, under different conditions or with varying input parameters.

One of the primary advantages of modelling and simulation is that it allows for the investigation of scenarios that may be difficult to replicate in the real world. For example, in environmental studies, conducting large-scale field experiments is often not feasible due to logistical or ethical concerns. In such cases, simulations provide a way to examine the potential outcomes of various interventions or policy decisions before they are implemented. Similarly, in engineering, simulations enable the analysis of systems under extreme conditions that might be hazardous to test physically.

The modelling process typically involves several stages, including the conceptualisation of the system, the identification of key variables and relationships, the formulation of the mathematical or computational model and the calibration and validation of the model against real-world data or experimental results. Once validated, the model can be used to simulate the system's behaviour under various hypothetical scenarios, providing valuable insights that can inform decision-making.

3.4 Facilitated Techniques

3.4.1 Policy intensity assessment

Policy intensity is a powerful tool for quantitative policy research (G. Zhang et al., 2022). It is an index that weighs various policies based on criteria, including whether they have quantifiable targets, set budgets, distinct objectives and timetables; whether they are integrated with other major policy efforts; whether policy monitoring is in place (Hu et al., 2020; G. Zhang et al., 2022). In the environmental policy domain, higher policy intensity implies higher costs of polluting behaviour or greater investment of resources, effort and activity (L. Li & Taeihagh, 2020). A policy intensity index is established through text analysis to assess policy intensity. Policy intensity reflects the government's attitude and enforcement intensity towards policy implementation, which is highly correlated with the scope and nature of the policy itself (G. Zhang et al., 2018). Table 3.2 lists the indicators' criteria and scores (GU et al., 2022; C. Liu et al., 2021; B. Zhu et al., 2021) to support the policy intensity assessment in Chapter 4. A higher policy intensity implies more vigorous policy enforcement.

The authority level consists of three criteria. Document types are assigned a value from 1 to 5, depending on the policy level. "Notice, Announcement or Letter" has the lowest value of 1. "Suggestion, Measure, Interim planning, Opinion or Rule" takes a lower value of 2. "Planning or Deployment" has a medium rank of 3. "Decision or Provision" scores 4. "Law or Local regulation" has the most significant enforcement effectiveness, with the highest rank of 5. The leading body is assigned a value from 1 to 5 according to the agency's administrative level. The national people's congress and state council represent the highest administrative and legislative organisations, respectively. Therefore, their published policy has a score of 5. Policy issued by the central ministry/commission or province-level/municipality-level people's congress/government has a value of 4, followed by province-level/municipality-level department or prefecture-level government policy with a value of 3. Meanwhile, policies issued by a prefecture-level bureau or district-level/county-level government are scored 2, while the policy is assigned the lowest value of 1 if the leading body is a district-level/ county-level bureau. Regarding the number of involved agencies, 1, 2 and 3 scores are respectively assigned, based on the number of involved agencies. The target type supports the target strength, and the score depends on whether the proposed goal is qualitative or quantitative. Vague qualitative goals have the lowest value of 1, while "Measurable, verifiable and detailed" goals score the highest value of 3. Policy intensity is calculated by multiplying the indicators' scores listed in Table 3.2.

Table 3.2 Hierarchical structure of policy intensity index (GU et al., 2022; C. Liu et al., 2021; B. Zhu et al., 2021).

Index	Indicator definition		Value
Policy enforcement intensity	Authority level	Document type	1= Notice / Announce / Letter
			2= Suggestion / Measure / Interim planning / Opinion / Rules
			3= Planning / Deployment
			4= Decision / Provision
			5= Central law / Local regulation
		Leading body	1= District-level or county-level bureau
			2= Prefecture-level bureau / District-level or county-level government
			3[*]= Province-level or municipality-level department / Prefecture-level government

		4[*]= Central ministry or commission / Province-level or municipality-level people’s congress or government
		5= National people’s congress / State council
	Number of involved agencies	1= One agency 3= Some agencies (2-4) 5= More agencies (≥5)
Target strength	Target type	1= Qualitative target 2= Some quantitative targets 3= Detailed quantitative targets

[*] Note: sub-provincial city adds a half-point.

3.4.2 Evolutionary game theory

Evolutionary game theory is the application of the mathematical framework of game theory (Morgenstern & Von Neumann, 1953) to the dynamics of animal conflicts (and, of course, human-involved conflicts). Game theory offers a mathematical background for modelling rational systems and can generate solutions in situations of competition or conflict (Sikhar Barari et al., 2012). Game theory aims at deducing an appropriate strategy to resolve arising conflicts or finding the optimal sequence of decisions that yields the highest payoff. The mathematical foundations of game theory were originally derived from Morgenstern & Von Neumann (1953) and were later extended by Nash Jr (1950). Classical game theory operates on the assumption that participants possess complete information about the game and act as fully rational decision-makers. Game theory experienced a revival when Maynard Smith and Price turned their attention to evolutionary game theory.

Evolutionary game theory was developed to predict the distribution of individual behaviours in biological systems in which a single species has evolved through natural selection (Maynard Smith, 1974; Smith & Price, 1973). The theory's predictions of equilibrium behaviour correspond to intuitive static solutions to games formed by comparing the fitness (e.g., payoff) of different behaviours (e.g., strategies). A fundamental consequence is that under a stable behavioural distribution, no individual in the population can improve its fitness by unilaterally changing its strategy. "Evolutionary stable strategy" (ESS), which Maynard Smith first used to describe an action (or game) in the sense that an animal choosing it would guarantee an evolutionary advantage over a rival, is a strategy that will never go extinct (However, it could need to coexist with other ESSs). The concept of ESS is more refined compared with Nash equilibria (rational choice of strategies in economic games). Although every ESS is a Nash equilibrium, certain Nash equilibria are not ESS due to that they are unstable fixed points of evolutionary dynamics (e.g., Hofbauer & Sigmund, 1998; Smith, 1982).

Evolutionary game theory extends beyond its biological origins and has become a valuable tool for analysing human and social behaviour (Cressman & Apaloo, 2018). Rather than relying on natural selection, changes in strategy frequencies here emerge as individuals or groups adjust behaviours based on observed payoffs. Unlike classical game theory, which assumes complete rationality, evolutionary game theory acknowledges bounded rationality; participants, constrained by incomplete information, may not immediately make optimal choices. Instead, they progressively reach ESSs through iterative learning, imitation and adaptation. This approach has proven effective for policy-making (K. Fan & Hui, 2020) and fostering stakeholder cooperation (Nagarajan & Sošić, 2008) by allowing dynamic modelling of participant behaviour and the effects of external environmental factors (Z. Liu et al., 2021).

Given that GB promotion is a systemic and long-term process rather than an instantaneous change, evolutionary game theory offers a fitting analytical framework to capture its complexities and dynamics. This approach has already shown utility in the GB sector for examining the dynamic interactions among stakeholders (e.g., L. Chen et al., 2021; K. Fan & Hui, 2020; Y. Lin et al., 2024; Lu et al., 2022; Y. Zhao et al., 2024). In this study, evolutionary game theory is applied in Chapter 5 to investigate the dynamic behaviours of the central government, local governments and developers in the context of GB promotion.

3.4.3 Principal-agent theory

The principal-agent theory is typically recognised as a crucial component of the economics of organisations, such as business companies or governments, that consist of, or at least include, agency relationships: a contract whereby one or more persons (principal) choose another person (agent), granting the agent some decision-making authority to perform certain tasks on their behalf (Buchanan, 1988). The core of principal-agent theory is a contract that specifies decision rights (Wohlstetter et al., 2008). In particular, what agents should do, and what principals must do in return. This connection comes with built-in control issues (Wohlstetter et al., 2008), wherein the principal designs an incentive mechanism to induce the agent to act in a way that maximises the principal's interests. Consequently, principal-agent theory is essentially a theory of contract design.

The theory is based on two primary assumptions: (1) the goals of the agent and the principal are in conflict and (2) information asymmetry exists due to the agent's superior knowledge (Laffont & Tirole, 1993). As a result of this conflict of interest and asymmetry, the agent may be incentivised to act in ways that deviate from the principal's interests, potentially causing losses for the principal. This deviation contradicts the principal's original intent, necessitating the use of a contractual framework to reward or penalise the agent based on observable outcomes, thereby aligning both parties' interests (Zhang W., 2004).

Information asymmetry, from a temporal perspective, can be classified into ex-ante and ex-post categories. Ex-ante asymmetry exists prior to contract formation, while ex-post asymmetry arises after the contract is established. These categories contribute to two specific problems: moral hazard and adverse selection. Moral hazard is the term used to describe an agent's actions that, after signing a contract, maximise their personal profits at the expense of the principal (Laffont & Martimort, 2002). Adverse selection refers to the fact that the agent conceals the cost, output and other information before signing the contract for his/her own interest, which leads to the distortion of contract prices and a decrease in market efficiency. Additionally, information asymmetry can pertain to behaviour or knowledge, leading to moral hazard and adverse selection, respectively. Designing an optimal contract (incentive mechanism) enables the principal to mitigate these issues by addressing information asymmetry (J. Li et al., 2019). To address moral hazard, the principal aims to incentivise the agent to adopt actions that maximise the principal's benefits. After the contract is signed, although the principal can observe the agent's performance outcomes, monitoring the agent's precise actions, such as effort level, is challenging. Since random external factors influence output, it becomes difficult for the principal to discern whether outcomes are genuinely due to the agent's actions. The agent, however, has private information about their effort level and market conditions. This discrepancy may lead the agent to reduce effort or engage in actions unrelated to or even detrimental to the contract's objectives, thus harming the principal's interests. Given the principal's inability to observe the agent's private information, research on moral hazard focuses on designing contracts that encourage the agent to act in the principal's best interest, such as maximising effort.

To tackle adverse selection, the principal's objective is to encourage the agent to disclose accurate information via carefully designed contracts. Before the contract is established, the principal lacks accurate information regarding the agent's cost structure or abilities. Suppose the principal offers a contract based on an average performance assumption. In that case, higher-level agents may react passively or withdraw, while the principal responds by lowering incentives, creating a cycle in which “bad money drives out good money”. The screening model addresses this issue, wherein the principal, though uninformed of the agent’s true level, offers multiple contracts, allowing the agent to self-select according to their attributes, thereby enabling information screening.

3.4.3.1 Multi-level principal-agent theory

Traditional principal-agent theory typically examines single-principal and single-agent relationships. However, in complex settings, both principal and agent may adopt multiple roles, resulting in a dual or multi-level principal-agent structure (Lin C., 2014). The dual principal-agent theory builds on traditional single-agent frameworks to address governance within entities where ownership is concentrated (Feng G., 2004). Multi-level principal-agent theory extends this model to account for nested intermediary roles. For instance, shareholders act as principals to company management, which in turn acts as principals to staff. This intricate and layered structure necessitates analysing not only the principal-agent dynamics at each level but also the effects of intermediary roles on the overall system.

Multi-level principal-agent theory has extensive applications in public policy, particularly in understanding the relationships between different levels of government and between governments and regulated enterprises (Chen F. & Wang, 2004). Public policy formulation and implementation inherently involve contractual issues such as information asymmetry, moral hazard and adverse selection (Bergman & Lane, 1990). For example, X. Yang et al. (2021) applied multi-level principal-agent theory to design an optimal contract promoting dual economic growth and environmental sustainability objectives, considering the dual agency dynamics within decentralised governance. Similarly, Yan et al. (2021) analysed benefit distribution in China’s rural collective commercial land market from a multi-level principal-agent perspective, devising a mechanism to optimise stakeholder interests, enhance land use efficiency and facilitate policy execution. These studies underscore the prevalence of multi-level principal-agent relationships in policy implementation, demonstrating that multi-level principal-agent theory can be an effective tool for designing optimal policies to improve governance effectiveness.

3.4.3.2 Principal-agent model

Principal-agent theory employs mathematical models to examine how principals design incentive mechanisms for agents. At its core, the theory seeks to establish an effective incentive structure (contract) that aligns the interests of principals and agents, encouraging agents to pursue principals' objectives and fostering a mutually beneficial outcome. Specifically, it investigates the dynamics of risk-sharing, profit distribution and incentive design, focusing on devising a property rights structure and principles for incentive mechanisms that address the fundamental issues within the principal-agent relationship. The objective is to create incentives that enhance agents' motivation and productivity while ensuring alignment with principals' interests.

A principal-agent model typically consists of three essential components: (1) the principal's expected utility function; (2) the agent's individual rationality constraint and (3) the agent's incentive compatibility constraint. The individual rationality constraint, also known as the participation constraint, requires that the agent's utility from participating in the contract be at least equal to the utility they would receive by not participating; otherwise, the agent would choose to abstain. Incentive compatibility, on the other hand, refers to a mechanism wherein each participant achieves their optimal outcome by acting according to their true preferences (Hurwicz, 1960). In other words, under a well-designed mechanism, each participant is incentivised to disclose their private information honestly, leading to an equilibrium where all participants pursue strategies that reflect their best interests. This ensures that the mechanism serves each participant's self-interest and aligns with the broader goals set by the mechanism designer.

Put simply, participation constraints guarantee that agents are motivated to engage in the arrangement, as they obtain at least equivalent utility by participating; incentive compatibility constraints ensure that agents are incentivised to act in a way that aligns with the principal's desired actions. In an optimal solution, the agent's compensation for achieving the principal's goals is designed to be at least as beneficial as any alternative outcome, thereby fostering alignment with the principal's objectives.

Although the majority of the early work on principal-agent theory concentrated on formal contracts, more recent work has extended the framework to relationships involving different levels of government (e.g., B. Lin & Xie, 2023; Petersmann, 2008; Tommasi & Weinschelbaum, 2007; Wood, 1988; X. Yang et al., 2021; W. Zhang, 1998). This study draws on principal-agent theory to consider how to best achieve GB promotion in MLG system in Chapter 6.

3.4.4 Techniques for empirical validation

To validate the research results derived from the mathematical analyses, this study employs a combination of statistical techniques, including one-sample *t*-tests and ordinary least squares (OLS) regression. The *t*-tests are used to examine whether the sample means of key variables significantly deviate from hypothesised values, while the OLS regression quantifies the relationships between independent and dependent variables. Control variables, such as demographic characteristics, are included in the regression models to account for potential confounding factors.

3.4.4.1 One-sample t-test

One-sample *t*-tests are employed to validate hypotheses derived from theoretical frameworks or qualitative insights (Ross & Willson, 2017). These tests provide a quantitative measure of whether observed sample means significantly deviate from hypothesised values, which are often informed by theoretical or non-statistical considerations. While the *t*-test itself is a quantitative method, it serves as a tool to validate qualitative assumptions or theoretical models empirically. This method assumes that the data is normally distributed. The *t*-test statistic is computed as:

$$t = \frac{\bar{x} - \mu}{s/\sqrt{n}}$$

Where $\bar{x}$ is sample mean, μ is hypothesised mean, s is sample standard deviation and n is sample size. The degrees of freedom for the test are calculated as:

$$df = n - 1$$

The result of the *t*-test is compared to a critical value from the t-distribution table at a predefined significance level (e.g., 0.05). The decision rule is: if $|t| > t_{\text{critical}}$, the null hypothesis H_0 (that the sample mean equals the hypothesised mean) is rejected; if $|t| \leq t_{\text{critical}}$, the null hypothesis H_0 is not rejected. Equivalently, if $p \leq \alpha$ (e.g., 0.05), reject H_0; otherwise, fail to reject H_0. For hypotheses derived from theoretical models, the *t*-test provides a statistical means of validation, bridging the gap between qualitative insights and empirical evidence.

3.4.4.2 OLS regression

Regression, unlike correlation, takes into account how one quantity is influenced by another (Lindley, 1990). Regression analysis is a statistical technique for investigating relationships between variables (Sykes, 1993) and assumes an asymmetrical dependence between the variables being studied (Lindley, 1990). The OLS regression model (Chumney & Simpson, 2006) is employed to examine the relationships between key independent variables and dependent variables. This method provides quantitative insights into the strength and direction of these relationships. The general form of the regression equation is:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \epsilon_i$$

Where Y_i is the dependent variable for observation i, $X_{1i}, X_{2i}, \dots, X_{ki}$ are the independent variables for observation i, β_0 is the intercept term, $\beta_1, \beta_2, \dots, \beta_k$ are the coefficients representing the effects of independent variables and ϵ_i is the error term.

The coefficients β are estimated using the formula:

$$\hat{\beta} = (X^T X)^{-1} X^T Y$$

Where X is the matrix of independent variables, Y is the vector of dependent variable observations and $\hat{\beta}$ is the vector of estimated coefficients.

3.5 Chapter Summary

This chapter presents a comprehensive methodology framework integrating qualitative and quantitative approaches to address the research objectives. It begins by outlining the overarching research framework, summarising the methods and analytical techniques used, including document analysis, modelling and simulation, questionnaire surveys and expert interviews. This chapter then elaborates on these methods, highlighting their relevance and adaptability for achieving the research objectives, such as exploring GBP dynamics, stakeholder behaviours and policy incentive mechanisms. Finally, this chapter introduces the facilitated techniques employed for data analysis and validation, including policy intensity assessment, evolutionary game theory, principal-agent theory and empirical validation techniques such as one-sample *t*-tests and OLS regression. These methods collectively provide a robust foundation for analysing GB promotion under China's MLG system.

CHAPTER 4 Green Building Policies in China: A Comprehensive Review and Analysis[1]

4.1 Introduction

Motivated by GBs' advantages, the Chinese government has released multiple GBPs to support and promote GB widely. Owing to policy support, the number of newly constructed GBs in China has generally increased over the past decade (Y. Shen & Faure, 2021). Policies, formulated by party and government agencies and other organisations, serve as actions and guidelines intended to achieve political, cultural, economic, social and ecological goals. These policies encompass a range of forms, including laws, regulations, measures, decisions and government documents, all aimed at advancing national and societal progress. The GBPs, specifically pertain to policies affecting the entire lifecycle of GBs (Matisoff et al., 2016).

Although research on China's GBPs is increasing, few studies analyse these policies from the perspective of the policies themselves. Policy texts, colloquially referred to as "red-headed documents" (Huang C. et al., 2015), serve as the physical embodiment of policies (Li J. et al., 2015) and play a significant role in governmental activities in China (Huang C. et al., 2015). Investigating policy texts provides empirical data and objective descriptions, thereby grounding policy research in reliable factual bases (Li J. et al., 2015). This approach facilitates a thorough examination of the intrinsic logic and external articulation of policy documents, uncovering intentions and objectives of policymakers and providing valuable insights and references for policy formulation and implementation.

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[1] This chapter is relevant to the publication:

Hu, Q., Xue, J., Liu, R., Shen, G. Q., & Xiong, F. (2023). Green building policies in China: A policy review and analysis. *Energy and Buildings*, *278*, 112641.

Studies based on the perspective of the GBP itself are limited to (1) static pattern (Y. Shen & Faure, 2021; J. Xiao et al., 2024), ignoring the dynamic evolution of GBPs; (2) partial object scope, focusing only on a sub-topic (e.g., green retrofit (G. Liu et al., 2020) and green residential buildings (J. Wu & Ying, 2024)) and (3) national level (Gan et al., 2023; Z. Wu et al., 2021), lacking the GBPs issued by local governments. Local government policies are crucial as they directly impact the development of GB within their jurisdictions and are an essential component of the overall GBP framework.

A systematic understanding of the policies' patterns, characteristics and evolution is a prerequisite for optimising the entire process of policy initiation, formulation, design, implementation, management and evaluation (B. Zhu et al., 2021). Furthermore, comparisons between the central and local GBPs can help policymakers and researchers further unearth how the Chinese governments govern GB development and determine how to advance GB governance through upcoming policies under a MLG system.

Thus, this chapter reviews and analyses the structure and trends of China's central and local GBPs systematically using the mixed content analysis method. It begins with a comparative analysis of central and local policies and divides the development of GBPs into three stages along the timeline. Then, to present the governments' dynamic actions and solutions, the characteristics of each stage are determined through a chronological review of policy content with the help of extracted high-frequency keywords. Meanwhile, to fully understand multi-level governments' preferences and attitudes towards GBP implementation, the central and local governments' historical evolutions of policy structure are analysed, and their corresponding enforcement intensities are evaluated. Based on that, this chapter draws a clear picture of GBP development in China's MLG context, summarises the characteristics of the policy system, identifies related shortcomings and provides a foundation for subsequent modelling.

4.2 Research Design

Figure 4.1 illustrates the research methods and flows. First, data collection and processing aim at collecting GBPs comprehensively. After screening the initial policy documents retrieved from the PKULAW database and official websites, a total of 1,727 GBPs are obtained. Then, the mixed content analysis method, which combines text-mining, qualitative, content and quantitative analysis is performed to review and analyse the GBPs quantitatively and qualitatively. Specifically, the content review and analysis enable the coding and categorisation of GBPs and the determination of their policy content, including objectives, implemented time, innovation points and issuing bodies. Text-mining and quantitative analyses are performed to support the comprehensive understanding of GBPs from the perspective of policy hotspots, structure and intensity. Accordingly, a full picture of the current GBPs in China can be ascertained. Finally, the results of the policy documents are explored further in terms of trajectory, characteristics and challenges.

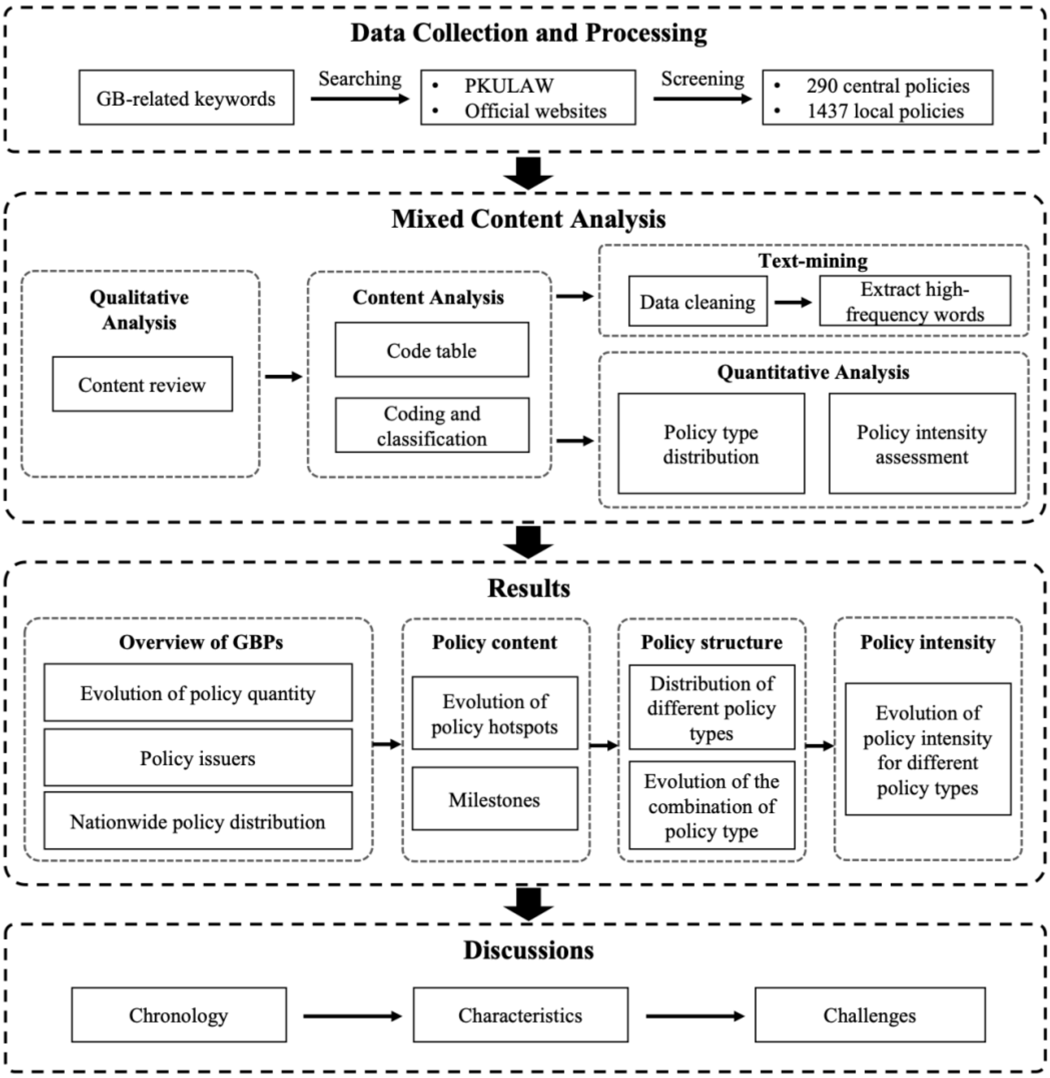


Figure 4.1 Research framework in Chapter 4.

4.2.1 Data collection and processing

The data used in this chapter are based on China's GBPs at all governmental levels. Specifically, it refers to policies formulated by the central and local governments and relevant departments in various forms, including laws and regulations, aimed at promoting the adoption of GBs. Two types of data sources are used to ensure the integrity of the dataset: (1) all levels of governmental websites and (2) PKULAW Database (https://www.pkulaw.com), which is the largest and most up-to-date database of Chinese policy in full text and has successfully provided reliable data for policy research across multiple fields, including but not limited to disaster management (Q. Zhang et al., 2018), artificial intelligence (C. Yang & Huang, 2022), resource recycling (Yao & Zhang, 2018), air pollution control (Du et al., 2021), urban residential heating (B. Zhu et al., 2021) and GBs (Z. Wu et al., 2021).

The keywords for the search included “green building”, “sustainable building” and “ecological building”. After retrieving the policies, the policy texts that directly reflect government attitudes, such as laws, regulations, provisions, decisions, plans, suggestions, opinions, measures, notices and announcements, are chosen. In contrast, official endorsements of proposed policies are excluded. Then, the collected texts are examined and texts with less frequent keyword combinations are removed. Repeated policy content in search results is also excluded. Finally, 1,727 GBPs texts from 2004 to 2023 are obtained through search and screening: 290 central government policy documents and 1,437 local government policy documents.

To investigate the regional distribution of GBPs at the local level, the 31 provinces/municipalities of mainland China are divided into the eastern, central and western regions following their geographical locations, which have been widely used in China’s regional studies (C. C. Fan & Sun, 2008). The eastern region consists of the following 11 provinces/municipalities: Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang. There are 8 provinces in the central region: Anhui, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangxi and Shanxi. 12 provinces, municipalities and autonomous areas make up the western region: Gansu, Guangxi, Guizhou, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Sichuan, Xinjiang, Yunnan, Chongqing and Tibet. Due to data availability and different policy systems, GBPs in Hong Kong, Macau and Taiwan are not within the scope of this study.

4.3 Results

4.3.1 Overview of GBPs

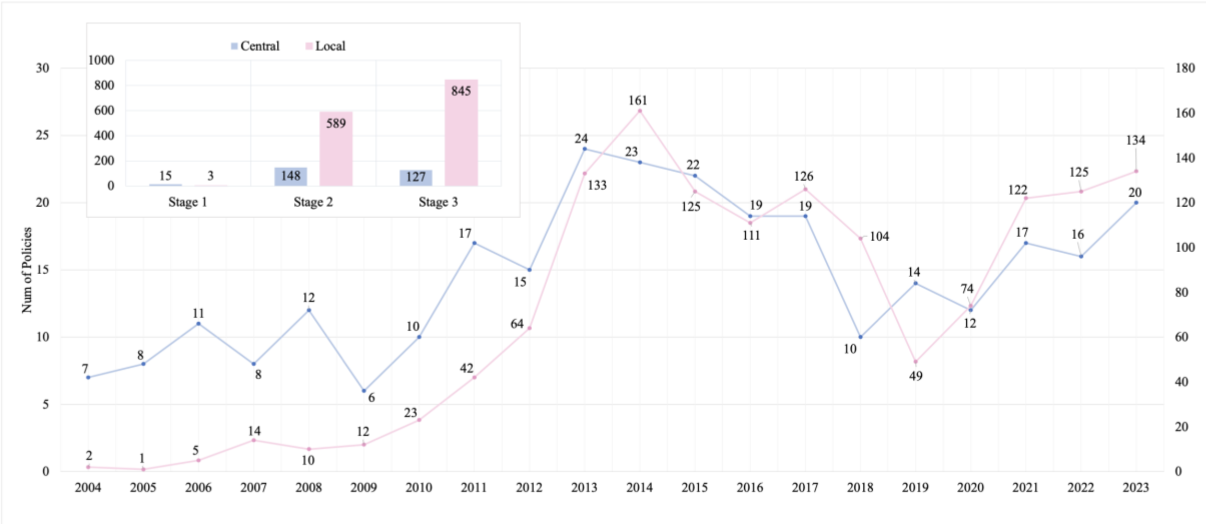


Figure 4.2 Distribution of GBPs in China (2004–2023).

This subsection presents an overview of GBPs from the perspective of policy issuance time, quantity, region and unit based on the content review and quantitative analyses.

Given the tremendous changes to national strategies and issuing significant policies, the GBPs are divided into three stages: Stage 1: infancy and exploration (2004–2005), Stage 2: rapid development (2006–2015) and Stage 3: further enhancement (2016–2023). In Figure 4.2, the number of central and local policies reached a peak in Stage 2, which also has the largest policy quantities. The annual number of central and local policies fluctuates, with central policies peaking in 2013 (24 policies) and local policies peaking in 2014 (161 policies). With a lag of around a year, the overall trend in the number of local policies is overwhelmingly compatible with that of the central policy, which may be influenced by the significant events and essential policies of the central government in the preceding year. Local governments should implement the policies willingly or obligatorily after the central government introduces them. Therefore, local governments may implement particular policies in the same year or the year after.

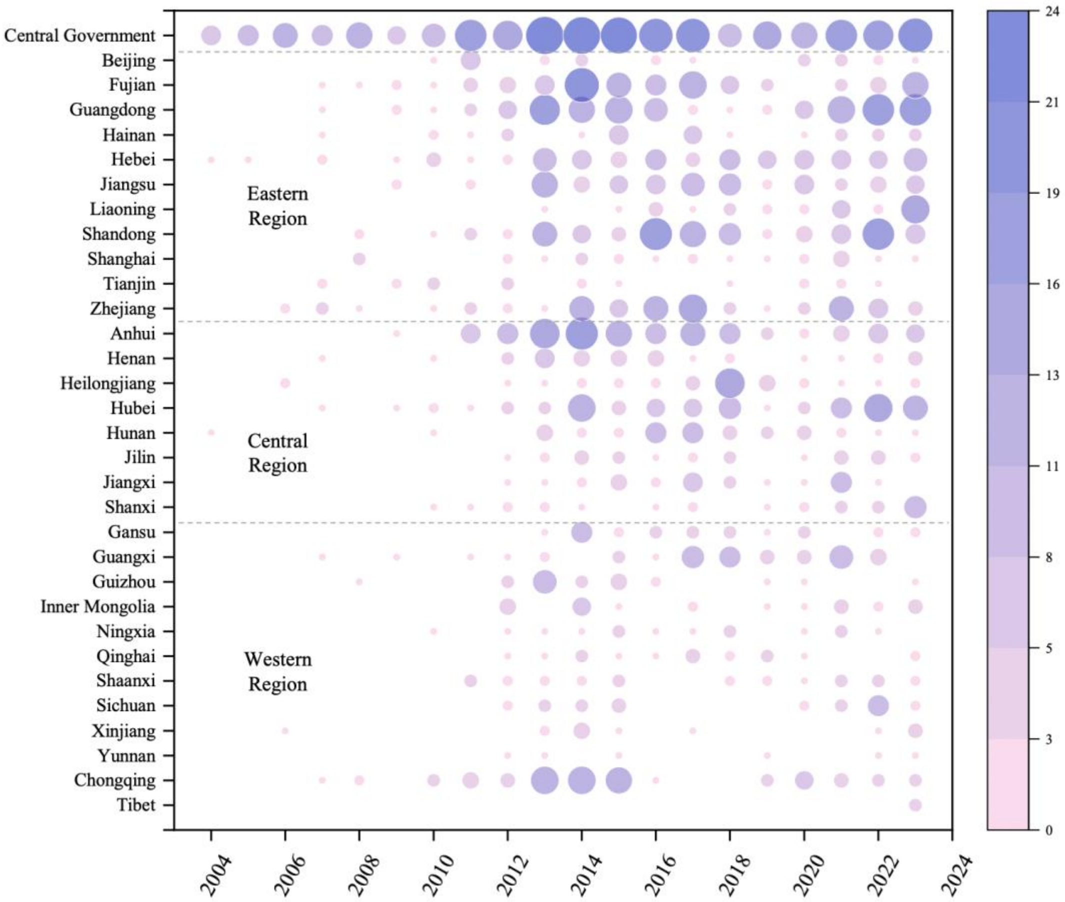


Figure 4.3 Spatial-temporal distribution of GBPs in China.

Figure 4.3 shows the GBPs by issued time and regions. A larger node implies a larger number of issuances. Since 2004, GBPs began to spread to the local level in relatively developed eastern and central regions, forming a top-down vertical diffusion dimension. Only two provinces started exploring the concept of GB management during the initial stage. The horizontal diffusion of local GBPs in the eastern region exploded in 2007–2008, followed by the central region in 2009–2010 and finally in the western region in 2011–2012. From 2013 to 2018, massive local policies were released. The issued GBPs show temporal continuity in the eastern and central regions compared to the western region. Notably, 2013 and 2020 are the turning points that witnessed significant changes in the number of local GBPs. By 2022, 30 provinces/municipalities responded to central GBPs by enacting applicable policies. Tibet was the only province that had not issued any policies by this time. It was not until 2023 that Tibet issued its first GBP. Furthermore, GBPs vary widely across regions. The eastern region promulgates the most policies (654), followed by the central region (370) and the western region (285). As far as specific provinces/municipalities are concerned, Guangdong issues the most policies (122), followed by Anhui (111) and Shandong (106). Two of the three provinces with the most policies are in the eastern region.

In terms of issue units, for central policies, the Ministry of Housing and Urban-Rural Development and State Council dominate, launching the most policies. Among 290 national-level policies, 234 policies were released independently by individual departments, accounting for 80.69%; 23 were released jointly by two issuers, while the other 33 were issued by three or more departments, accounting for 19.31%. For local policies, the provincial/municipal governments and the Department/Bureau of Housing and Urban-Rural Development dominate. Among 1437 local-level policies, 1340 were independently released by individual departments, accounting for 93.25% of the total. 97 were released jointly by multiple departments, accounting for 6.75% of the total. Concerning different regions, joint policy issuances accounted for 6.91%, 8.85% and 3.59% of the total policies issued in the eastern, central and western regions, respectively. Joint policy issuances generally reflect the degree of communication, cooperation and coordination among multiple departments (H. Zhang et al., 2020). Thus, the central government forms deeper cooperation and pays more attention to coordination among departments when formulating GBPs, followed by the central, eastern and western regions.

4.3.2 Policy content: a review of the evolution of GBP

Combining the high-frequency keywords extracted by the text-mining method at different stages, this subsection captured the historical development of GBPs in China through content analysis. Table 4.1 summarises the emerging high-frequency keywords related to GBPs.

Table 4.1 Emerging high-frequency keywords related to GBPs.

Stage	Word and Frequency
Infancy and exploration stage (2004–2005)	Technology (1047), Development (693), Build (513), Research (470), Environment (279), Resource (272), Energy-saving (209), Innovation (163), Declaration (109).
Rapid development stage (2006–2015)	Standard (7757), Unit (5701), Design (5084), Management (4792), Retrofit (4769), Implementation (4523), Pilot (4217), Label (4168), System (3671), Construction (3543), Evaluation (2814), Public buildings (2663), Local (2215), Fund (1056), Encouragement (722).
Further enhancement stage (2016–2023)	Review (3396), Provision (3193), Inspection (3055), Acceptance (2964), Supervision (2936), Reformation (2391), Full implementation (1947), Examination (866), Compulsory (623), High-quality (602), Penalty (518).

4.3.2.1 Infancy and exploration stage (2004–2005)

Before 2006, GB governance was in its infancy, and few policies were issued. Generally, the central administration dominated the GB governance at this stage. Figure 4.2 shows that only 15 documents from the central government and 3 from local governments were issued. This suggests that local governments did not prioritise GB because the central government's objectives were too general and non-mandatory. The first two responding provinces were Henan and Hunan, which promulgated policies in 2004. In this phase, the concept of GB emerged, and the central government's attention shifted from the original energy-saving building to GB, which is more eco-friendly and stresses energy-saving, land-saving, water-saving and material-saving, thereby minimising adverse effects on the environment throughout the life cycle. This concept is known as “Four-saving and One-benign” (Y. Li et al., 2014). Therefore, the keywords “development”, “environment”, “resource” and “energy-saving” were highly used at this stage.

“Green building” first occurred in the national policy in 2004, encouraging enterprises to participate in GB-related innovations (mainly technological innovation). Words such as “technology”, “research”, “innovation” and “declaration” appeared at a high frequency. Particularly, the central government launched the Green Building Innovation Award (Ministry of Housing and Urban-Rural Development, 2004) and Technology Project (Ministry of Housing and Urban-Rural Development, 2005) to stimulate GB development. In 2005, the Ministry of Housing and Urban-Rural Development and the Ministry of Science and Technology jointly issued the “*Green Building Technical Guidelines*” to guide and standardise the development of GB by local governments and enterprises and explore economic and sustainable alternatives for promoting GBs (Ministry of Housing and Urban-Rural Development & Ministry of Science and Technology, 2005). The guideline clarifies the definition of GB and provides theoretical support for the index system and technical points in the stages of planning and design, construction and operation management.

4.3.2.2 Rapid development stage (2006–2015)

The year 2006 featured a milestone: the central government issued the first assessment standard for GBs (GB/T50378-2006). This standard has played an essential role in regulating and guiding GBs in China, laying a solid foundation for forming the GB industry. Overall, the GBPs stepped into the diffusion stage. The emergence of keywords “management”, “system”, “evaluation”, “standard”, “pilot”, “label”, “encouragement” and “fund” shows that the GB management system gradually took shape with technical and financial support.

Initially off, this stage was large-scale and first introduced quantifiable targets. The national "Five-Year-Plan" (FYP) for 2011–2015 formally proposed that the construction industry should promote GB and construction, and GB was first written into China's national plan. Passive ultra-low energy buildings, prefabricated buildings, nearly zero-energy buildings and green ecological urban areas were introduced in GBPs to enrich the GB scope. Meanwhile, the quantitative goals of GB adoption rate evolved from 15% to 50% in new urban buildings, and it became mandatory for large-scale public buildings to follow GB standards and be green. Thus, "public building" appeared at a high frequency. Some local governments set more ambitious goals, such as Guangzhou, Foshan and Dongying in Guangdong Province, requiring all new construction or renovation projects to meet the one-star standard. Moreover, the target for GB pilot numbers grew from 30 to 100.

In 2013, the "*Green Building Action Plan*" marked the official launch of the national GB action (China Academy of Building Research, 2017), after which local policies exploded. In stark contrast to previous provincial-level government-led governance, more and more municipal governments became involved in issuing relevant policies. The frequent occurrence of "local" and "unit" suggests that local governments and departments were more actively engaged in GB governance.

Regarding technical support, this stage established and improved the GB standard system because several standards were developed and issued in the succeeding years. In particular, assessment standards cover almost all lifecycle stages of all building types in most regions (Ye et al., 2015). Regarding the lifecycle stage, GB standards cover the stages of design, operation, construction and refurbishment or retrofitting for factories, offices, stores, hospitals, hotels and school campuses, respectively, in terms of building types. Regarding regions, 21 provinces/municipalities localised and launched their standards.

4.3.2.3 Further enhancement stage (2016–2023)

The emergency keyword “high-quality” shows the government’s ambitious goal and improving requirements at this stage. In 2019, China redefined GB in response to changes in the major social contradiction proposed by the 19th National Congress of the Communist Party of China. In “*Assessment Standard for Green Buildings*” (GB/T50378-2019), “high-quality” is added before “building”. Meanwhile, to be consistent with the people’s needs for a better life in the new era, the word “people” is added before “harmonious coexistence with nature”, and the word “maximum” is moved to the front of “people” rather than “resource-saving”, demonstrating the focus of GB has shifted from resource conservation to reaching the harmony between human and nature. This fully embodies the principle of “people-oriented” and enhances the attention of GBs to users themselves (X.-J. Li et al., 2021). In the following 2020, the “*Green Building Creation Action Plan*” (Ministry of Housing and Urban-Rural Development et al., 2020) was enacted jointly by 7 national departments to meet the inevitable requirements of GB development, stressing the people’s role in GB action as well as the regulation of demand-sided users. On the other hand, achieving the goal of carbon peaking and neutrality has put forward higher requirements for developing GBs in China. For instance, healthy buildings, zero-carbon buildings and green ecological communities are proposed, and 70% of new urban buildings will be green by 2022 (Ministry of Housing and Urban-Rural Development et al., 2020).

Unlike the previous stages, after 2015, the legal system of GB began to take shape. Keywords “provision”, “inspection”, “review”, “supervision” and “compulsory” emerged at this stage. 17 local governments launched GB regulations, of which 8 are from the eastern region, 6 from the central region and 3 from the western region. The regulations clarify mandatory requirements and responsibilities and promulgate quantifiable punishment measures. However, there is no GB law for the central government so far. In this context, the “*Green Building Creation Action*

Plan” and “*‘14th Five-Year’ Plan’ Building Energy Conservation and Green Building Development Plan*” emphasise the importance of GB legislation, requiring local governments to enact GB regulations to strengthen GB governance, which is conducive to promoting GB legislation at the national level. Apart from enacting regulations, the inspection of GB implementation of the lower government by the upper government also played an important role at this stage. The primary purpose of the inspection is to grasp the completion of GB tasks in various regions; thereby, deficiencies could be corrected promptly, and successful experiences and practices could be summarised and shared nationwide. Put simply, the government started establishing a comprehensive monitoring system to acquire timely GB information to ensure meeting the GB goals.

4.3.3 Policy structure: evolution of the combination of policy types

GBPs are grouped into five categories, namely, direction-based policies (DBPs), technical support policies (TSPs), financial support policies (FSPs), service-based policies (SBPs) and regulation-based policies (RBPs). Direction-based policies (e.g., plans and framework) offer a roadmap and future directions for promoting GB. Examples include “*The Ministry of Construction’s Notice on the 11th Five-Year Plan Outline of Construction*”, “*The Ministry of Housing and Urban-Rural Development’s Notice on Promoting One and Two-Star Green Building Evaluation Labels*” and “*The Ministry of Housing and Urban-Rural Development and Other Departments’ Notice on Issuing the Green Building Creation Action Plan*”. Regulation-based policies (e.g., laws and regulations) set the requirements for implementing GB. Examples include “*Regulations on the Use of Green Building Evaluation Labels (Trial)*”, “*The Ministry of Housing and Urban-Rural Development’s Notice on Conducting Special Inspections on Building Energy Conservation, Green Buildings and Prefabricated Buildings in 2017*” and “*Guangdong Province Green Building Regulations*”. Technical support policies support governments’ objectives through standards, codes and guidelines. Examples include “*The*

Ministry of Construction and Ministry of Science and Technology's Notice on Issuing the Green Building Technical Guidelines" and "*The Ministry of Housing and Urban-Rural Development's Announcement on the Release of the National Standard for Green Building Evaluation Standards*". Financial support policies are through subsidies, funds, tax exemptions or deductions, loans, etc. Examples include "*The Ministry of Housing and Urban-Rural Development's Notice on Issuing the Detailed Rules for the Implementation of the National Green Building Innovation Award and the National Green Building Innovation Award Evaluation Standards*" and "*Anhui Provincial Department of Finance's Notice on Issuing the Interim Measures for the Management of Special Funds for Green Buildings in Anhui Province*". Service-based policies provide service and information to promote GB through pilot, organisation, professional training, information sharing, propaganda, declaration, etc. Examples include "*The Ministry of Housing and Urban-Rural Development Building Energy Conservation and Technology Division's Notice on Hosting the Green Building Evaluation Label Expert Training Conference*" and "*The Ministry of Housing and Urban-Rural Development's Notice on Organising Applications for the 2020 Science and Technology Plan Projects*". The following quantification analysis is conducted from the perspective of central and local governments to gain the evolution of policy type. Moreover, statistical results of different regions in three periods are integrated into Table 4.2 for comparison and illustration. Figure 4.4 depicts the distribution of various policies issued by the central government. The total number of DBPs is 184, contributing the largest proportion at 62.59%, followed by SBPs at 16.67%, TSPs at 8.84%, RBPs at 7.82%, and FSPs at 4.08%. The most employed GBP is DBP. Except for 2008, 2010, 2015 and 2020, such policy accounts for more than half of the annual GBPs. Second to DBP, SBP receives volatile but generally rising attention from the central government. From 2004 to 2019, SBP ranged from 0 to 4 (averagely 13.23%). That number then jumped to 6 (50%) in 2020. Furthermore, TSP receives less attention than the above two policies. Such a type of policy was concentrated in Stage 2, which aimed to establish the GB technical system. Compared with the other types of GBPs, the central government largely ignores policies related to RBPs and FSPs. In 2008, there was a peak for RBP. At that time, the central government was devoted to regulating GB labels. FSPs occupied a large proportion in 2004, indicating that the central government offered financial incentives to stimulate GB promotion in its infancy period; however, this type of policy was largely ignored in Stage 3. Overall, the central government prefers DBP, and this type is overused, underscoring the planned and methodical approach the central government has taken to the development of GB.

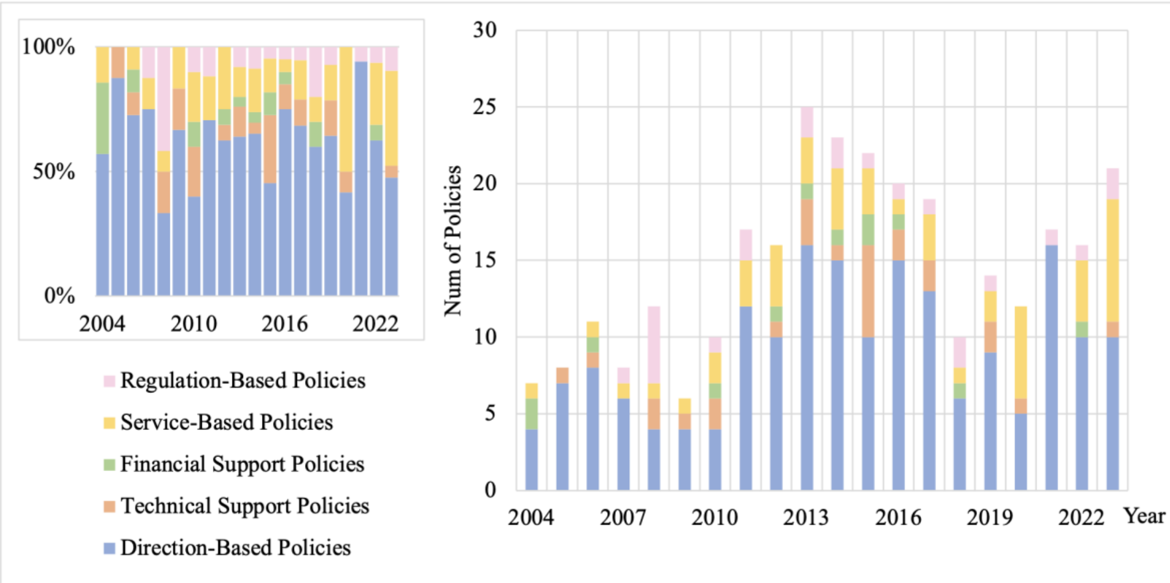


Figure 4.4 Distribution of policy types for China’s central government.

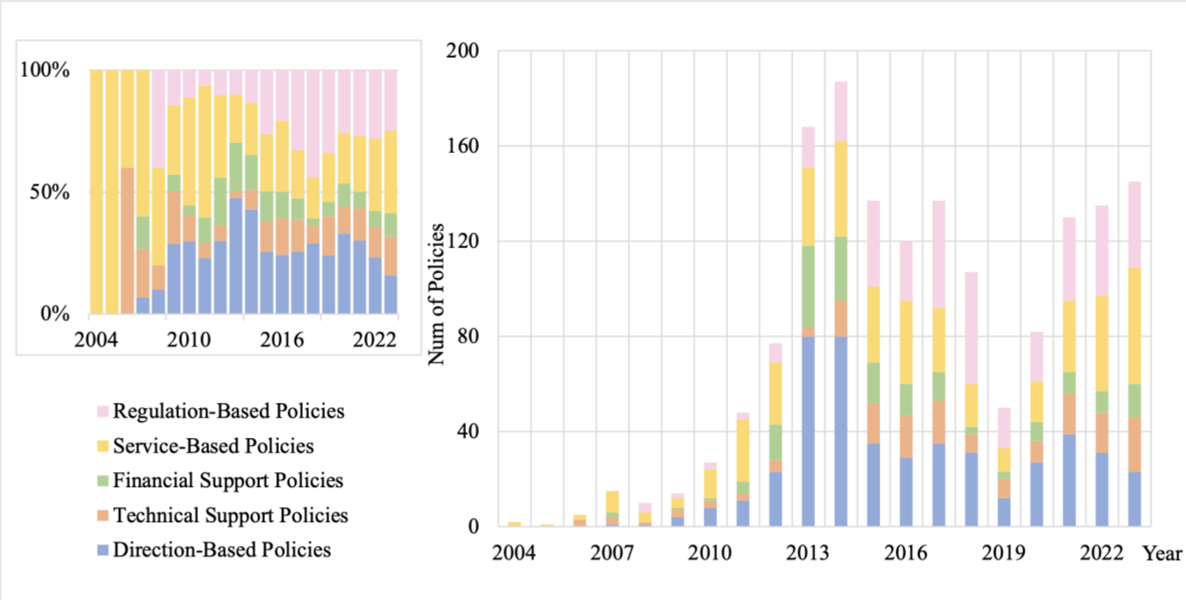


Figure 4.5 Distribution of policy types for China's local governments.

Figure 4.5 depicts the distribution of local governments' policy types. Unlike the structure where DBPs significantly dominate central GBPs, local governments have a more balanced distribution of policy types. The total number of DBPs is 470, accounting for the largest proportion at 29.43%, which decreases compared with the central government but remains the greatest, followed by SBPs at 26.11%, RBPs at 22.67%, TSPs at 10.96% and FSPs at 10.83%. Regarding the temporal dimension, different from the central government's GBPs, SBP was the only type introduced by local governments in Stage 1. Such type of policy becomes less regarded over time. DBPs published by local governments increased in Stage 2 and decreased in Stage 3. Similarly, the proportion of RBPs at the local level peaked in 2008. Starting from 2008, RBPs received fluctuating attention in Stage 2 and became dominant in Stage 3. TSPs occupied a large part at the beginning of Stage 2, indicating that some more developed cities were responding to build the technical system of GB. In 2012, the central government introduced an incentive scheme (Ministry of Finance & Ministry of Housing & Urban-Rural

Development, 2012), and since then, a wide range of FSPs has begun to be released. This policy became less popular in Stage 3 as local governments stressed their roles in regulation.

Table 4.2 Spatial-temporal distribution of policy types.

Region	Stage	DBPs	FSPs	SBPs	RBPs	TSPs
Central government	Stage 1	73.33%	13.33%	6.67%	0.00%	6.67%
	Stage 2	59.33%	4.67%	15.33%	9.33%	11.33%
	Stage 3	65.12%	2.33%	19.38%	6.98%	6.20%
	All stages	62.59%	4.08%	16.67%	7.82%	8.84%
Local government	Stage 1	0.00%	0.00%	100.00%	0.00%	0.00%
	Stage 2	35.32%	14.83%	27.33%	14.24%	8.28%
	Stage 3	25.06%	7.84%	24.94%	29.14%	13.02%
	All stages	29.43%	10.83%	26.11%	22.67%	10.96%
Eastern region	Stage 1	0.00%	0.00%	100.00%	0.00%	0.00%
	Stage 2	35.67%	14.02%	26.83%	15.55%	7.93%
	Stage 3	23.96%	8.96%	29.79%	22.92%	14.38%
	All stages	28.64%	10.99%	28.77%	19.88%	11.73%
Central region	Stage 1	0.00%	0.00%	100.00%	0.00%	0.00%

	Stage 2	34.44%	16.11%	29.44%	15.00%	5.00%
	Stage 3	26.79%	7.17%	17.74%	38.87%	9.43%
	All stages	29.82%	10.76%	22.65%	29.15%	7.62%
Western region	Stage 1	0.00%	0.00%	00.00%	0.00%	0.00%
	Stage 2	35.56%	15.00%	26.11%	11.11%	12.22%
	Stage 3	25.47%	5.59%	22.36%	31.68%	14.91%
	All stages	30.79%	10.56%	24.34%	20.82%	13.49%

From the spatial dimension, DBPs are the most applied policies across all regions. Beyond that, each region has its preferred policy components. The eastern region launched more FSPs (10.99%) than the central (10.76%) and western regions (10.56%). Among them, Shandong is in a leading position in the formulation of FSPs in the eastern region. A series of provincial and municipal FSPs have been introduced to incentivise GB promotion, with detailed objectives and support conditions. The central region prefers RBPs (29.15%) compared with the western (20.82%) and eastern regions (19.88%). In detail, Hubei and Anhui actively participate in regulating GBs by issuing policies, especially carrying out special inspections. The western region issues more TSPs (13.49%) to promote GB compared with the central (7.62%) and eastern (11.73%) regions. Chongqing and Guangxi in the western region take the lead in formulating TSPs, enacting a series of standards and targeting various stages (e.g., design, inspection and quality acceptance).

Table 4.2 shows the spatial-temporal distribution of policy types. Comparative analyses of the central and local policy types reveal that the central government takes its guiding role in

China's GB development, launching a large number of DBPs at each stage. DBPs shared the largest portion in Stage 1, providing an initial development roadmap for GB at the beginning. The portion of DBP decreased in Stage 2 but rebounded in Stage 3, mainly because the central government exerted efforts to establish the GB technology system through TSPs and SBPs in Stage 2, laying a solid base for GB promotion. The portion of DBP increased in Stage 3 because new requirements for high-quality GB emerged during this period. Thus, the central government applied more DBPs to guide the large-scale development of high-quality GB. Moreover, at the central and local levels, FSPs took a relatively larger share in the initial stage with the aim of motivating stakeholders. However, FSPs have obtained less attention over time. Unlike the central government, the local governments' RBPs became predominant in Stage 3, indicating that government supervision has aroused significant concerns. However, central government oversight is insufficient.

Overall, a streamlined policy framework initially guided GB development in China and gradually became more diverse as theory and practice developed. Specifically, in the beginning, the central government adopted a more comprehensive policy framework, including DBP, SBP, FSP and TSP, while local governments only issued SBPs to provide information to GB stakeholders, indicating that local governments are conservative and unwilling to take risks, taking a "wait-and-see" attitude towards the development of GB. Local governments only began to introduce diverse policies as the central government introduced more policies, indicating the central government's determination to promote GB.

4.3.4 Policy intensity: evolution of enforcement for different policy types

Government policy initiatives are one way to promote GB, but greater enforcement of these policies is also essential and will affect GB adoption (Darko & Chan, 2017). Policy intensity is quantified in this sub-section to illustrate the dynamic implementation of GBPs over the years.

Figure 4.6 displays the average changes in policy intensity for different policy types at the central and local levels during each stage. Significant differences in governments' enforcement of different policies can be observed. In general, SBP gains relatively low attention compared with other types. Besides, except for DBP, the central government generally presents stronger enforcement. The enforcement of FSP is a priority for both the central and local governments to promote GB.

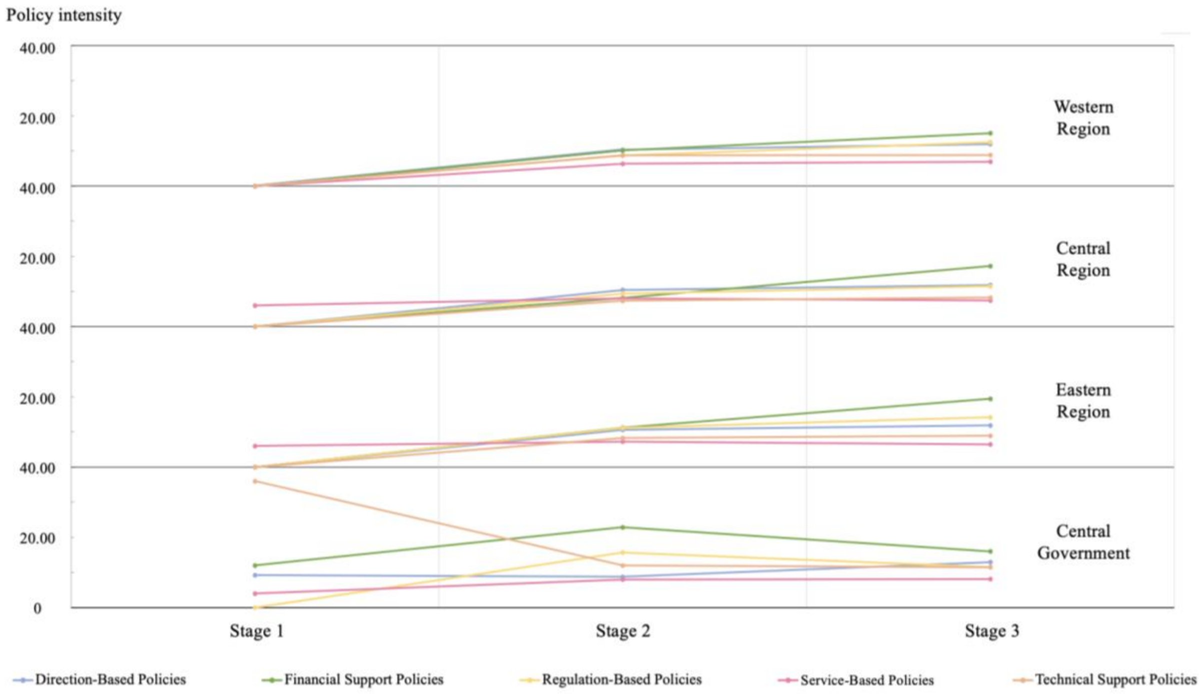


Figure 4.6 Policy intensity of GBPs in China.

The policy intensity varies for the central government. The policy intensity of SBP demonstrates a continuous upward trend, while TSP shows a continuous downward trend. The central government has exerted considerable efforts in enforcing TBP at the very beginning to guarantee the foundation of GB development. The DBP shows a V-shaped trend, while FSP and RBP illustrate an inverse V-shaped trend in the timeline. The central government shifted from TSP in Stage 1 to RBP and FSP in Stage 2 and then to DBP and FSP in Stage 3.

For local governments, most types of policies show increasing policy intensity. All regions show rising policy intensity of RBP, DBP, FSP and TSP, reflecting that more attention and improvements are devoted to these policies. However, the results depict obvious regional heterogeneity. On average, the eastern region conducts stronger enforcement, followed by the central and western regions. The three regions place a high priority on FSP in Stages 2 and 3. Furthermore, even though RBP ranks second in the eastern region, its policy intensity is still higher than that of other regions in both stages. The western region stresses RBP in Stage 3, while the central region favours higher DBP policy intensity over RBP in both stages. In addition, the intensity of SBP in the eastern and central regions shows a moderately declining trend, while the western region shows a slight increase.

4.4 Development, Characteristics and Challenges of China's GBP System

Section 4.3 reviewed and analysed China's GBPs at both central and local levels from various dimensions. This subsection synthesises the development and characteristics of China's GBP system, identifying the challenges it faces.

Based on the chronological review of GBP content and the analysis of policy structure and intensity from the above subsections, a comprehensive picture of GBP evolution in China can be presented in Figure 4.7. It summarises the GBP milestones from Section 4.3.2, showing the remarkable transition at different stages. The historical development of GBP evolved from the "Infancy and Exploration" stage (2004–2005), when there were few local responses, to the "Rapid Development" stage (2006–2015), when a comprehensive technical system developed, and finally entered the "Further Enhancement" stage (2016–2023) towards a legal system and high-quality goals.

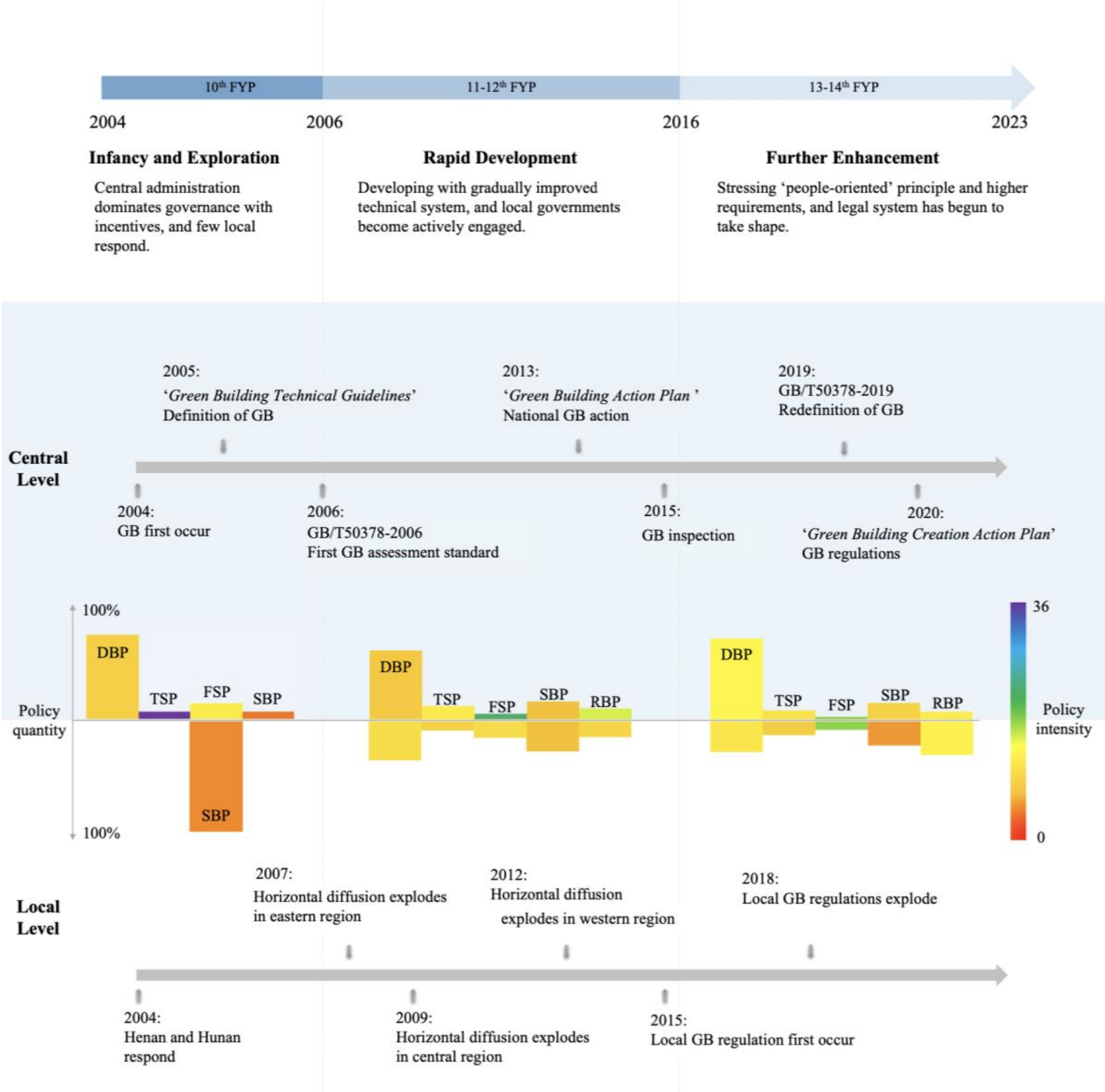


Figure 4.7 Chronology of GBP development and milestones in China.

Central and local governments have different policy structures and intensities at each stage. In Stage 1, the central government adopted a more comprehensive and powerful policy structure, while local governments preferred a simple policy framework and were reluctant to implement policies vigorously. In Stage 2, RBPs were introduced into the policy structure at the central and local levels. From the policy quantity and intensity perspective, the central government pays uneven attention to different types. Specifically, it releases many DBPs with low policy intensity, while FSPs and RBPs with minor releases have high policy intensity. In contrast, GBPs issued by local governments are more balanced, with smaller differences in enforcement intensity. The central government emphasises DBPs in Stage 3 and strengthens their implementation. The rest of the GBPs are less of a concern than Stage 2. By contrast, local governments prefer RBP in Stage 3. Except for SBP, the policy intensity of other types increases.

To sum up, as China's sustainable reform process progressed, the GBPs of local governments have generally been improved and strengthened over time due to a series of landmark central policies; however, the central government has prioritised different policies at different stages and typically focused on policy implementation in Stage 2. Second, the FSP, despite its small proportion in terms of quantity, is high in intensity at both central and local levels, underscoring the government's commitment to these policies. Third, local governments have been focusing increasing attention on RBP and TSP in terms of intensity and quantity. Furthermore, while DBP quantitatively dominates central government policy, its intensity is moderate.

4.4.1 Characteristics

Supported by the comprehensive reviews and quantitate analysis of the GBPs, the characteristics of China's GBP system are summarised as follows:

4.4.1.1 "Top-down" GBP system

From the evolution of policy content and spatial-temporal distribution of GBPs (e.g., Figure 4.3), a systemic governance system dedicated to promoting GB in China has emerged. Because of the negative environmental impact of the construction industry, the central government has introduced a large portion of DBPs, highlighting its leading role in GB development. Most local governments have responded by issuing policies to carry out central mandates. Every accelerated diffusion of GBPs at the local level is related closely to the top-level design at the central level. For example, the "*Green Building Action Plan*" launched in 2013 and the "*Green*

Building Creation Action Plan" launched in 2020. Such a governance system is characterised as a "top-down" mode and has evolved dynamically in various contexts.

Specifically, the central government was the main policymaker, and the GB governance remained at the central level in Stage 1. In Stage 2, because of the central government's lead and strong enforcement, the GB governance extended to the local level, province/municipality- and prefecture-level governments actively complied with the central government's guidance. In Stage 3, the central and local governments proceeded to overhaul the GB governance system in concert, thereby strengthening supervision by better-clarifying responsibilities and conducting inspections of lower-level actors. Meanwhile, some provinces and cities introduced quantifiable penalties for violations. Overall, the central government leads policy formulation and promotion, while local governments are responsible for implementation and enforcement, creating a coordinated and interactive relationship between central and local governments.

4.4.1.2 Expanded scope and more ambitious goal

Based on policy content and structure evolution (e.g., Figures 4.4 and 4.5), the GBPs have expanded in scope and set a more ambitious goal. After decades of development, the scope of GBs has been broadened from a single GB to passive ultra-low energy buildings, prefabricated buildings, nearly zero energy buildings, green ecological urban areas, healthy buildings, zero-carbon buildings and green ecological communities. The scope of GBP guidance has also been extended from the design or operation stage to all life cycle stages. A comprehensive standard system provides quantifiable criteria, laying a technical foundation for regulating the GB market and guiding GB development. The scope of the GBP framework evolved from single SBPs to comprehensive utilisation of DBPs, SBPs, FSPs, TSPs and RBPs. The scope of GB supervision has been expanded from the supply to the demand side, stressing the regulation of GB users to ensure the GB's efficiency at the operation stage (Ministry of Housing and Urban-Rural Development et al., 2020). Likewise, the priorities of GB have shifted from resource-saving to reaching harmony between humans and nature, highlighting the "people-oriented" principle. Moreover, increasing environmental concerns have resulted in the ever-increasing demands for GB promotion. The latest plan sets the goal for all new town buildings to be constructed entirely as GBs by 2025 (State Council, 2021).

4.4.1.3 Establishment of "carrot-and-stick" incentive mechanism

The evolution of policy structure and intensity (e.g., Figures 4.4, 4.5 and 4.6) shows that the FSP made up a relatively large proportion in the initial stage and then gradually decreased, but its intensity increased. RBP is introduced in Stage 2, and its intensity gradually increases. Thus, it is evident that "carrots", that is, the financial support (FSP), were popular at the beginning stage of GB development, providing incentives to overcome economic barriers. At that time, there were no RBPs at the central and local levels. Realising the "carrots" were neither sufficient nor efficient to achieve promising progress, the government combined "sticks"– the stricter mandates to promote GB (Olubunmi et al., 2016; Sentman et al., 2008). The "carrot-and-stick" mechanism with strong incentives and supervision began to take shape in Stage 2, replacing the previous single "carrot" mechanism.

Specifically, the FSP issue has decreased, but its intensity is strong, including subsidies, land transfers, tax reductions, loans, awards and floor area ratios. Financial subsidies remain a commonly used positive incentive, such as the central government's special funds for energy conservation and emission reduction, and local rewards measures for GB projects in cities like Chongqing, Shandong, Shanghai and Beijing, offering subsidies ranging from 15 yuan/m² to 80 yuan/m² for different star-level GB projects. RBP has become popular with increasing intensity, especially at the local level, with penalties for non-compliance being common negative incentives. For instance, the "*Green Building Regulations*" in provinces like Guangdong, Zhejiang, Liaoning, Hunan and Jiangsu specify penalties ranging from 50,000 to 500,000 yuan for developers violating GB standards. Meanwhile, to supervise the implementation of GB, the upper-level government assigned specific top-down distribution targets that consider regional heterogeneity (Ministry of Housing & Urban-Rural Development, 2013; Ministry of Housing and Urban-Rural Development, 2012). Fulfilments of such assigned targets would be linked to the performance and promotion of local officials. Overall, incentives and supervision remain crucial for current GB promotion, combining “mandatory” and “incentive” approaches to advance GB development. This helps to achieve expanded goals and improve GB promotion.

4.4.2 Challenges

Although the GBPs have been continuously revised and updated to enhance their feasibility at the central and local levels, they still encounter substantial challenges, particularly in the context of a MLG system and an uncertain economic environment. This subsection summarises the following key challenges:

4.4.2.1 Conflicts of interest and non-cooperative games under MLG

The “top-down” GBP system inherits the characteristics of China’s governance structure, where fiscal responsibilities are dispersed across multiple government levels, yet centralised governance prevails with strong top-down mandates (X. Zhang, 2006) that leads to inconsistency in the interests of central and local governments, thereby hindering the implementation of GBPs (Lieberthal & Oksenberg, 1988; Zou et al., 2017).

During the promotion of GBs, both central and local governments represent the fundamental interests of the people. However, subtle differences between central and local considerations in policy implementation can lead to interest conflicts. These differences result in a non-cooperative game scenario where both central and local governments seek to maximise their interests while coexisting harmoniously. The central government emphasises environmental protection and sustainable development alongside economic growth, supporting GB promotion. Conversely, local governments prioritise local economic development. Firstly, the central government delegates the allocation of numerous public goods to local governments, requiring them to manage local public goods distribution autonomously. To fulfil this responsibility, local governments must ensure sufficient fiscal resources to support societal functions, necessitating prioritisation of rapid local economic development to generate tax revenue and fiscal income. Secondly, the current evaluation system places significant weight on local economic performance, influencing the central government's assessment of local governments. This prompts local governments to focus on economic development, not only to ensure social and governmental stability but also to enhance their political influence and prospects for promotion within the political hierarchy. The proportion of GBs in government evaluation systems is relatively small, with their primary value reflected in environmental and social benefits, which may not yield significant economic returns in the short term. Compared to other projects with quicker economic returns, local governments may strategically implement GBPs to a minimal extent, furthering the divergence between central and local policy goals and hindering effective GB promotion.

Particularly, the central government is only responsible for setting GBPs and targets (Kostka, 2016), and the launched policies often leave space for flexible implementation (Lo, 2014), with local governments responsible for implementing them. Although local governments possess less authority compared to the central government, they retain considerable discretion, enabling them to exert significant influence in the design and implementation of local development initiatives. Consequently, some local governments may, due to factors such as the externalities of GBs, enforcement costs, economic pressures, and "blame politics", weaken their responsibility to promote GBs as mandated by the central government, opting instead to merely meet minimum requirements (Ran, 2017; Zhou Y., 2021). This results in incomplete enforcement, implementation lag, weak efficiency, insufficient incentives for GBPs, and a significant conflict with central policy objectives. For example, the central government promulgated financial incentives to GB stakeholders in 2012, including 45 yuan/m^2 for two-star GB and 80 yuan/m^2 for three-star GB (Ministry of Finance & Ministry of Housing & Urban-Rural Development, 2012). However, this policy neither clarifies which level(s) the local government should pay nor specifies punishment for non-compliance. Accordingly, local governments flexibly choose to follow this policy based on the fiscal budget. The "*Regulations on Green Building Development in Hunan Province*", for example, included incentive measures for two-star and above GBs but did not specify the amount or source of funding, nor did it detail the central fiscal incentives, resulting in poor operability and limited incentive effectiveness. A similar situation also happens with other types of policies, resulting in an unbalanced GB development among cities and, sometimes, collusion between local governments and firms (Fredriksson & Millimet, 2002; Y. Qian & Roland, 1998; H. Wu et al., 2020).

4.4.2.2 Regional inequalities

The spatial distribution of local GBPs varies among regions; the policy quantity, type and intensity have regional imbalances (e.g., Figures 4.3, 4.6 and Table 4.2), indicating notable differences in the implementation of central policies across regions. In general, the eastern region enacted more GBPs and put higher policy intensity on average, followed by the central and western regions. Regarding specific policy types, the eastern region has issued more FSPs, while the other regions have adopted different policy types.

The results are rational because of the prolonged regional inequalities in China. Drawing on regional differences in the number (Zou et al., 2017) and promotion efficiency (L. Chen, Chan, Darko, et al., 2022) of GBs, the following analysis is conducted. Despite tailored TSPs based on local climate and economic factors, such as provincial "*Green Building Evaluation Standards*", providing technical foundations and guidance for GB development, the MLG system allows local fiscal autonomy. The formulation and implementation of GBPs require substantial investment, disadvantaging economically weaker areas (Lee & Koski, 2012). Additionally, due to the longstanding regional development inequalities in China (Xin-gang & Fan, 2019), the economic capacity of the eastern region is stronger than that of the central and western regions (C. C. Fan & Sun, 2008). The central region is geographically close to the eastern region, with middle-level economic capacity among the three regions (S. Zhou & Zhou, 2021), which may explain why the eastern region is more active in launching GBPs to promote GB, especially by offering FSPs and imposing stronger policy enforcement, thereby achieving notable success. Comparatively, the central region has opted for RBPs to safeguard GB implementation. However, most are non-GB regulations with insufficient enforcement intensity, which has narrowed the gap with GB development in the eastern region to a certain extent but remains inefficient. The western region has issued the fewest GBPs with generally low enforcement intensity and the least success in GB promotion.

4.4.2.3 Lack of effective incentive mechanisms

The implementation of GBPs in China involves multiple stakeholders, including various levels of local governments and developers. To ensure effective policy implementation, a well-designed incentive mechanism must be established, incorporating appropriate social compensation or rewards and, when necessary, proportional penalties to uphold social equity in GB promotion. However, despite the emphasis on the "carrot-and-stick" incentive mechanism, current fiscal incentive and regulatory policies lack adequate compensation (rewards) and penalty mechanisms.

On the one hand, the main entities promoting GBs do not receive adequate and reasonable compensation or rewards for bearing social costs, rendering FSPs ineffective in providing positive incentives. For example, current GBPs do not market-price the social externalities of GBs for effective compensation, causing promoters to bear high social costs. For local governments, limited central incentives and incomplete special funding policies to match GB promotion goals deter full implementation, such as establishing and enforcing incentive and regulatory mechanisms as required by the central government. Consequently, developers, as primary implementers of GBPs, lack the motivation to develop GBs, potentially leading to illegal behaviours like false reporting and subsidy fraud. Empirical evidence shows that even with government subsidies, current incentives are insufficient to cover developers' "green transition" costs (H. Jiang & Payne, 2019). As profit-driven entities, developers can only pass these costs onto consumers, yet studies (e.g., H. Jiang & Payne, 2019) indicate low consumer acceptance of GBs, exacerbating the promotion dilemma.

On the other hand, there is a lack of effective negative incentives for non-compliance with GBPs. Although the GBP system identifies local governments as responsible for promoting GBs, it does not specify the political and legal obligations of governmental departments and leaders, especially concerning specific corrective and punitive measures for policy violations. This may lead to poor supervision, inadequate incentives and lax enforcement, fostering local governments' passive policy implementation. China's mandatory GB regulations are relatively few, operating in a flexible policy environment where local governments can choose whether and how to implement them. The overlapping of departmental functions further complicates issue resolution. Even accountability measures may fail due to insufficient or weak punitive measures, lacking deterrence and prevention effects. Additionally, while the central government actively plays its guiding role by issuing a large number of DBPs, it somewhat ignores its regulatory role (with a small proportion of RBPs launched and decreasing enforcement intensity). This ignorance leads to inefficient GBP implementation and GB promotion. Although the central government has introduced central inspections and self-reporting to monitor GB implementation, both methods have limitations. Central inspections are infrequent and pre-announced (Lo, 2020), which leaves room for preparation. The self-reporting system, requiring provincial governments to submit annual self-evaluation reports to the Ministry of Housing and Urban-Rural Development, is quite susceptible to data manipulation (Lo, 2014). Even if central inspections uncover passive local behaviours, there is a lack of clear punitive measures to restrain such actions, limiting GB development. Legislation is fundamental to promoting GB (Y. Li et al., 2014). However, the GBP at the central level lacks laws and regulations suited to its context, meaning local governments adopting passive or compromise strategies in GBP implementation do not face legal consequences.

4.5 Chapter Summary

This chapter utilises a mixed content analysis method to systematically review and examine 1,727 GBP texts issued in China from 2004 to 2023. It provides an in-depth analysis of the development, characteristics and challenges of China's GBP system from the perspectives of the government level to which the policy belongs, the spatio-temporal distribution of the policies and the historical evolution of the policy content, structure and intensity. This analysis is of significant importance for optimising GBPs and promoting GB development. The following conclusions are drawn:

1. The historical development of China's GBP has evolved through three stages: the "Infancy and Exploration" stage (2004–2005), where the central government issued numerous DBPs to promote GBs, but due to the low intensity and incomplete structure of these policies, local governments rarely responded. The subsequent "Rapid Development" stage (2006–2015) witnessed an increase in policy intensity and structural improvements, eliciting a progressive response from local governments and leading to policy diffusion. During this period, both central and local governments continuously issued and revised TSPs, thereby forming a comprehensive GB technical standard system and laying a solid foundation for future development. Finally, "Further Enhancement" stage (2016–2023) involved the central government proposing "high-quality" development goals, with local governments responding positively,

strengthening policy intensity and issuing more RBPs aimed at establishing a legal framework to safeguard policy objectives.

2. The characteristics of China's GBP system are reflected in the following aspects: First, it adopts a "top-down" pattern, wherein the central government continuously promulgates policies to promote implementation, while local governments respond by issuing and executing these policies, thereby creating a coordinated and interactive relationship. Second, the scope of GBPs has progressively expanded, with policy goals being steadily elevated. Furthermore, a "carrot-and-stick" incentive mechanism has gradually been established and emphasised within FSPs and RBSs at various governmental levels.
3. The challenges of China's GBP system are reflected in the following aspects: First, the conflict of interests and non-cooperative dynamics between the central and local governments under the MLG structure make it difficult to effectively implement policies. Second, regional inequalities are evident, with the central and western regions lagging behind the eastern region in both policy implementation and GB development. Additionally, the lack of effective incentive mechanisms, as evidenced by the ineffectiveness of the existing "carrot-and-stick" mechanism, hampers the full achievement of policy goals.

In summary, to overcome the current developmental challenges of GBP system and promote the development of GB, it is essential to explore how to coordinate the conflicts of interest between central and local governments and other actors through scientific and reasonable policy formulation from the perspective of multi-level governments. This coordination aims to ensure the effectiveness of GBPs and alleviate regional inequalities. The findings underscore the importance of FSPs and RBPs (incentive mechanisms) in promoting GB development. However, existing policies lack effective incentive mechanisms. Thus, it is vital to focus on policy incentive mechanisms within China's MLG structure, elucidate their impact on GB promotion, and explore potential improvements. This approach will provide a foundation for optimising policy formulation and further promoting the healthy and stable development of the GB industry.

CHAPTER 5 Dynamic Behaviours and Evolutionary Paths of GB Promotion[2]

5.1 Introduction

Findings in Chapter 4 reveal that China's MLG structure exhibits variations in functional responsibilities and interests among different levels of government. As a result, distinct attitudes and behaviours in promoting GBs emerge, leading to a non-cooperative game relationship. Therefore, merely considering a single government level cannot fully reveal the behavioural mechanisms of GB promotion in China. China has adopted a "top-down" pattern in its GBP system, where the central government provides top-level designs to guide local governments in formulating and implementing specific public policies that align with local conditions. Such a policy system benefits from a clear division of government functions but risks policy ineffectiveness due to potential conflicts of interest between the central and local governments and between the government and other entities, such as developers.

Role differentiation and divergence in political objectives exist among governments at different levels. The central government formulates GBPs and supervises local government actions, while local governments are responsible for policy implementation within their jurisdictions. The strict adherence of local governments to central government directives significantly influences policy effectiveness. For instance, the National Audit Office has pointed out issues of non-standard management and utilisation of special funds for energy conservation and emission reduction in China, including insufficient oversight and inadequate fund allocation in some regions (*National Audit Office: Special funds for energy conservation and emission*

[2] This chapter is relevant to the publication:

Hu, Q., Xiong, F., Shen, G. Q., Liu, R., Wu, H., & Xue, J. (2023). Promoting green buildings in China's multi-level governance system: A tripartite evolutionary game analysis. *Building and Environment*, *242*, 110548.

reduction have problems such as irregular management and use, 2013). Existing research fails to reflect the heterogeneity between the central and local governments, neglecting their distinct interests and deviating from the actual conditions under China's current system.

Apart from the government, stakeholders involved in GB projects include developers, consumers, designers, suppliers and contractors. Their participation and interactions are crucial for the successful implementation of GBs (Y. Li et al., 2022). Among them, developers serve as the primary investors (M. Yuan et al., 2022), influencing design choices and construction methods adopted by designers and contractors. Their development intentions and technological capabilities have a direct and significant impact on the specific implementation of GBs (L. He & Chen, 2021), making developers key participants in determining the success of GB promotion. Developers, driven by profit-oriented motives and cost sensitivity in building product production (J. Hong et al., 2018), may lack sufficient motivation to invest in essential green technologies without government regulation in an immature GB market. Consequently, they become a primary target for government governance.

Prior to designing policy incentive mechanisms for promoting GBs in China, it is crucial to examine the behavioural mechanisms of stakeholders within China's institutional context. This investigation should consider multiple factors influencing effective promotion. Thus, this chapter develops a tripartite evolutionary game model involving key stakeholders—the central government, local governments and developers—based on the characteristics of the GBP system identified in Chapter 4. It explores the decision-making behaviour of each stakeholder and the influencing factors, uncovers the complex decision-making mechanisms among stakeholders in the MLG system, and examines system stability. A numerical analysis is then conducted to illustrate the evolution process and identify key factors in the GB promotion process. This model offers a more accurate reflection of the complex and dynamic interactions inherent in GB promotion.

This chapter presents a theoretical explanation for the challenges encountered in China's GB promotion, elucidates the role of policy incentive mechanisms and proposes strategies to foster cooperation among the three parties. These insights establish a theoretical foundation for effectively promoting GBs in China's MLG system.

5.2 Problem Description and Assumptions

5.2.1 Problem description

In the promotion of GBs, stakeholders (central government, local governments, and developers) engage in mutual gaming due to conflicting interests, leading to potential opportunistic behaviour in an information-asymmetric environment. It is essential to clarify that the game between the central and local governments discussed in this research operates under the unified leadership of the Communist Party of China and within the political system of the People's Republic of China. The stakeholders and behaviours studied herein are constructed within the framework of game theory, serving purely as theoretical tools to analyse GB promotion behaviours and policy implementation.

Among the three parties involved in GB promotion, the central government primarily represents the national interest, aiming for sustainable development and optimised political costs. GBs represent an innovative development model for the sustainable development theory in the construction industry (Taemthong & Chaisaard, 2019), effectively enhancing energy and resource efficiency and addressing government concerns over environmental protection and resources. Accordingly, the central government has formulated various GB-related policies and prioritises their development. Local governments, tasked with implementing GBPs within their jurisdictions, are responsible for formulating and enforcing related policies. Due to the lengthy information transmission chain between the central and local governments, and as the central government's agent, local governments may retain "private information" to some extent (K. Jiang et al., 2019), making it costly or difficult for the central government to fully ascertain local behaviours. As discussed in Chapter 4, under fiscal decentralisation, local governments, acting as “rational economic agents,” are more inclined to pursue local economic development. When the goal of promoting GBs conflicts with economic development, local governments exhibit a strong opportunistic tendency to downplay GB promotion in favour of economic growth. Fiscal decentralisation grants local governments decision-making autonomy, while the performance evaluation mechanism under political centralisation provides incentives and constraints on their decision-making. Insufficient central incentives or supervision may lead local governments to strategically implement central policies or even collude with enterprises to pursue economic benefits (K. Jiang et al., 2019; M. Liu & Lo, 2022). For instance, in enforcing GBPs, local governments may overlook compliance and regulation, adopting a lax attitude towards developers using non-green practices, creating a mutually beneficial scenario between government and enterprises, resulting in fewer and lower-quality GBs. Notably, while local governments do not intend to undermine sustainable development, they prioritise GDP growth, thus relegating environmental protection to a secondary position.

Developers, as GB suppliers, tend to maximise their economic benefits (K. Fan & Hui, 2020). Developing GBs incurs additional incremental costs, imposing greater economic pressure on developers. Additionally, the low market acceptance of GBs and the lack of high premiums to offset the incremental costs hinder the market mechanism from driving developers towards GBs. Coupled with information asymmetry, developers have a natural incentive to choose TBs over GBs, leading to opportunistic behaviours such as “GBs on blueprints” and non-compliant certifications (H. Jiang & Payne, 2019). Therefore, local governments need to rigorously enforce GBPs to address market failures, while the central government must strictly oversee policy implementation to mitigate the risk of policy failure. However, in an information-asymmetric environment, the government inevitably incurs high enforcement and supervision costs.

In addition to the conflicts and interactions between the central government, local governments and developers, consumers, as external variables, play a crucial role. Consumers, as the end-users of building products, exhibit varying preferences for the green attributes of buildings, and their willingness to purchase directly affects developers' investment decisions, thus influencing the effectiveness of GB promotion. Given the current low market acceptance of GBs, the existing market mechanism is insufficient to promote their development effectively. To address market failures, some proactive local governments have attempted consumer-side incentives, such as increasing housing provident fund loan limits, aiming to boost consumers' willingness to purchase and gradually develop a more robust market mechanism.

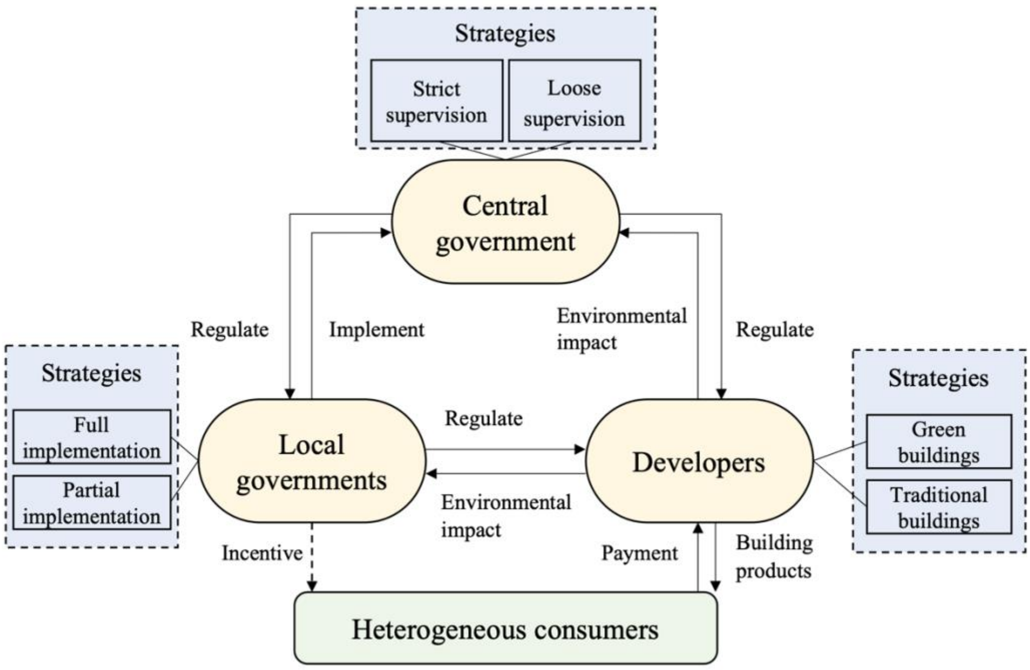


Figure 5.1 Green building promotion system.

Thus, this study examines a GB promotion system comprising the central government, local governments and developers, as shown in Figure 5.1. Developers construct and sell building products to heterogeneous consumers who choose between traditional and green buildings. The central government serves as the policy maker and supervises the behaviour of local governments and developers. Depending on the supervision cost, the central government may opt for strict or loose supervision. Local governments, as implementers of GBPs, decide whether to fully or partially implement the central government's policies based on their own interests.

5.2.2 Notations

For ease of description, the subscripts "c", "l", "d", "t" and "g" represent the "central government", "local governments", "developers", "traditional buildings" and "green buildings", respectively. The superscript "*" denotes the optimal solution. The variables, parameters and their corresponding definitions involved in the model of this chapter are presented in Table 5.1. The selection of parameters considers the results from Chapter 3 and previous studies.

Table 5.1 Parameters and variables symbol descriptions.

Parameters	Descriptions	Value range
S_c	Social benefits of the central government with strict supervision (e.g., international image, good reputation) (Cohen et al., 2019)	$S_c > 0$
E	Environmental benefits brought by the developers constructing GBs (e.g., environmental improvement) (Z. Wu & Ma, 2022; C. Zhao et al., 2022)	$E > 0$
α	The proportion of environmental benefits obtained by the central government	$0 < \alpha < 1$

G	Environmental governance costs paid by the governments with constructing TBs (Kulin & Johansson Sevä, 2019)	$G > 0$
β	The proportion of environmental governance costs paid by the central government	$0 < \beta < 1$
F	Reward to local governments with full implementation paid by the central government (e.g., Special Fund for Energy Conservation and Carbon Reduction) (Ran, 2013)	$F > 0$
J	Reward to developers paid by local governments (e.g., subsidy) (Y. Jiang et al., 2022)	$J > 0$
S_l	Social benefits of local governments with full implementation (e.g., good reputation, long-term economic benefits) (Y. Jiang et al., 2022)	$S_l > 0$
L	Economic losses of local governments with full implementation (Ran, 2013)	$L > 0$
P_c	Default penalty for collusion (B. Zhang et al., 2018)	$P_c > 0$
λ	Proportion of penalties paid by local governments	$0 < \lambda < 1$
P_d	Penalty for developers (e.g., fine) (Q. Feng et al., 2020)	$P_d > 0$
P_l	Penalty for local governments (e.g., administrative accountability)	$P_l > 0$
c_c	Costs of central government with strict supervision (X. Sun et al., 2021)	$c_c > 0$
c_l	Costs of local governments with full implementation (X. Sun et al., 2021)	$c_l > 0$

R	Bribery costs of developers and rent-seeking benefits of local governments (K. Jiang et al., 2019)	$R > 0$
c_i	Cost of traditional and green buildings, $i = t, g$	$c_g > c_t > 0$ (Z. Wu & Ma, 2022; L. Zhang et al., 2018b)
p_i	Price of traditional and green buildings, $i = t, g$	$p_g > p_t > 0$ (L. Zhang et al., 2018b)
e_i	Greenness of traditional and green buildings, $i = t, g$	$e_g > e_t \geq 0$ (L. He & Chen, 2021)
γ	Green preference of consumers (L. Fan et al., 2018; Juan et al., 2017)	$\gamma > 0$
θ	Green preference payment coefficient (L. He & Chen, 2021)	$\theta > 0$
μ	R&D cost coefficient (X. Wen et al., 2018)	$\mu > 0$
T	Reward to consumers (e.g., floating loan amount) (Q. Feng et al., 2020)	$T \geq 0$
Variables		
x	The probability that the central government adopts strict supervision	$0 \leq x \leq 1$
y	The probability that local governments fully implement GBPs	$0 \leq y \leq 1$
z	The probability that developers constructing GBs	$0 \leq z \leq 1$

5.2.3 Assumptions

Combined with the status quo and policies of China's GB promotion, some general assumptions regarding the actions of the three participants and the corresponding costs and benefits are provided as follows.

Assumption 5.1. Bounded rationality assumption. This assumption is set with reference to literature (K. Fan & Hui, 2020; X. Sun et al., 2021). The central government, local governments and developers have bounded rationality. They possess limited information, knowledge and resources, but they can learn and respond to changes in the environment and adjust their strategies through the GB governance process.

Assumption 5.2. Strategic assumption. This assumption is set with reference to literature (K. Fan et al., 2018; K. Fan & Hui, 2020; Y. Liu et al., 2022; W. Lu et al., 2022; Pan et al., 2023; X. Sun et al., 2021). In the GB governance system, the central government, a single entity with a "population" of strategies, decide between "strict supervision" (probability x) or "loose supervision" (probability $1-x$). Strict supervision will incur extra supervision costs c_c but receive social benefits S_c. Local governments, a population due to their multitude, follow "fully implement" (probability y) or "partially implement" (probability $1-y$) of GBPs. If local governments decide to implement GBPs fully, they will establish a policy incentive mechanism (including positive and negative incentives) to regulate the GB market. For instance, Guangdong Province in China has established fines ranging from 200,000 to 500,000 CNY for developers who fail to construct GBs. In terms of rewards, 25–45 CNY/m^2 will be rewarded for GBs, and the housing provident fund loan amount for GBs can be increased by about 10%. Fully implementation will incur extra costs c_l and economic losses L but receive social benefits S_l and additional special funds F from the central government. Otherwise, they will be punished when the central government inspects their partial implementation (P_l) and rent-seeking behaviours (λP_c). Developers, a population due to their multitude, adopt the construction of "GBs" (probability z) or "TBs" (probability $1 - z$). Constructing GBs will incur higher costs (c_g and $\mu {e_g}^2$) but receive reward J under local governments' reward-penalty mechanism. In this case, central and local governments can obtain environmental benefits E. Otherwise, developers will be punished (P_d), and governments must spend environmental governance costs G because of failure in GBP implementation. Moreover, developers will pay bribery costs R to avoid penalties for not building GBs, and local governments will not fully implement GBPs at this time. However, under the strict supervision of the central government, the collusion between developers and local governments will be detected and punished (P_c).

Assumption 5.3. Heterogeneous consumers assumption. Consumers have heterogeneous green preferences γ in the building market, and γ obeys a uniform distribution from [0,1] (L. He & Chen, 2021). Some consumers pay little attention to building greenness, whereas others are highly willing to purchase GBs, attributing additional value to their environmental benefits. Each consumer may have his/her most preferred building attributes and differ in taste. Thus, consumers acquire different utilities from buying GBs/TBs of the same greenness level. According to Mussa & Rosen (1978) utility function and L. He & Chen (2021), the consumer net utility for buying GB and TB is introduced as $U_g = \theta\gamma e_g - p_g + T$ and $U_t = \theta\gamma e_t - p_t$, respectively. Here, $\theta\gamma e_g(\theta\gamma e_t)$ refers to the GB's (TB's) value in consumer perception. θ is the payment coefficient of consumers' green preference, indicating the fee that consumers are willing to pay for each increase in building greenness. Besides the perception value, the consumer pays different prices to buy GB/TB, resulting in different utilities. Unlike buying TB, the consumer may obtain government incentives when buying GB.

A consumer who is indifferent between buying GB and TB is characterised by γ_1, indicating buying any of these two building types will receive the same utility: $\theta\gamma_1 e_g - p_g + T = \theta\gamma_1 e_t - p_t$. Thus, $\gamma_1 = \frac{p_g - p_t - T}{\theta(e_g - e_t)}$ can be obtained, where the consumer is indifferent between these two options. Accordingly, the relationship $0 \leq \gamma_1 \leq 1$ indicates heterogeneous consumers' purchase behaviours, and the market shares of these two buildings can be obtained. Customers distributed in $[0, \gamma_1]$ will buy TB and vice versa. Then, the profit functions for developers to build GBs and TBs can be obtained: $\pi_g = \frac{\left(T+2\theta e_g-2\theta e_t-c_g+c_t\right)^2}{9\theta\left(e_g-e_t\right)} - \mu {e_g}^2$ and $\pi_t = \frac{\left(T-\theta e_g+\theta e_t-c_g+c_t\right)^2}{9\theta\left(e_g-e_t\right)} - \mu {e_t}^2$. Where $\mu {e_g}^2$ and $\mu {e_t}^2$ represent the R&D costs of GBs and TBs, respectively (L. He & Chen, 2021). Notably, when local governments are partially implemented, there is no established reward-punishment mechanism. In this instance, $T = 0$. This chapter uses ${\pi_g}'$ and ${\pi_t}'$ to represent this situation.

Based on the above assumptions and notations, the expected payoffs of each player under different combined strategies are calculated in the game tree in Figure 5.2.

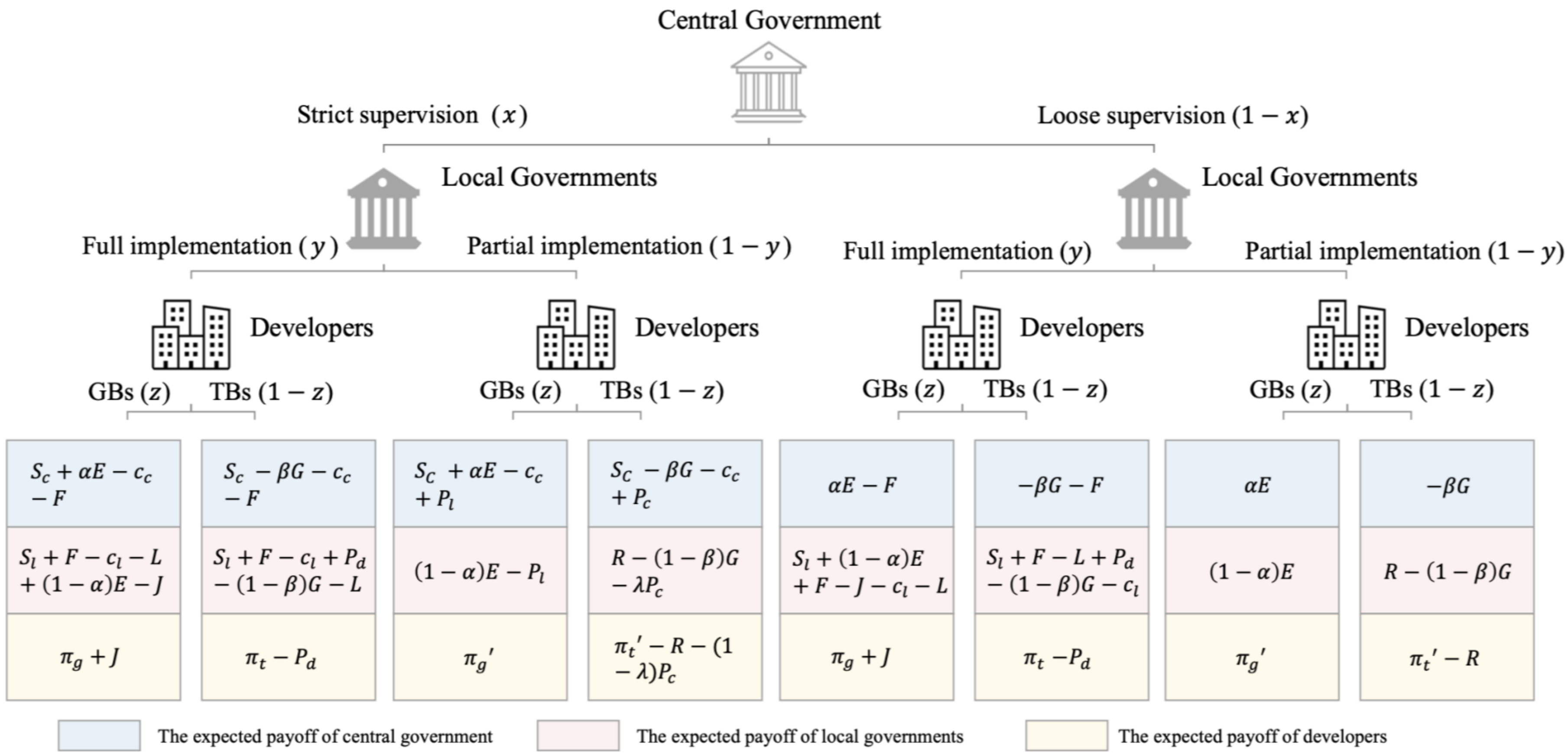


Figure 5.2 The tripartite game tree.

5.3 Model Development

5.3.1 Replicator dynamics equations

In an evolutionary system, the "fitness" of a strategy signifies its effectiveness. If a strategy's fitness exceeds the population's average, its adoption within the population increases, reflecting a "survival of the fittest" mechanism. This mechanism is common in natural selection processes, including human social systems (Tanimoto, 2021). Taylor & Jonker (1978) introduced replicator dynamics equations to model this mechanism. These equations describe the rate of change in the prevalence of a strategy over time. The use of successful strategies, which achieve higher payoffs than the average, is expected to increase in the next time step. On the other hand, the use of less successful strategies is expected to decrease. The degree of this change is believed to be determined by comparing it with the previously mentioned level of "success" (Tanimoto, 2021). The formula is:

$$\dot{p} = p_i(u_i - \bar{u}) \tag{5-1}$$

Where $\dot{p}$ represents the rate of change in the prevalence of i. p_i represents the current probability of the population adopting strategy i. u_i and $\bar{u}$ represent the expected payoff of strategy i and the average expected payoff of the population, respectively. The "survival of the fittest" selection mechanism is reflected in $\dot{p} > 0$. For example, if engaging in the development of GB yields higher returns, thus demonstrating higher adaptability, it will steer more developers towards choosing to develop GBs.

According to the tripartite game tree shown in Figure 5.2, the expected payoffs of each player choosing different strategies and their average expected payoffs can be determined. Afterwards, the replicator dynamic equations of each player can be calculated. The process of constructing the replicator dynamic equations of the central government, local governments and developers is as follows.

(1) The central government's expected payoffs of "strict supervision" and "loose supervision" strategies and the average expected payoff are shown in U_{c1}, U_{c2} and $\overline{U_c}$:

$$U_{c1} = yz(S_c + \alpha E - c_c - F) + y(1-z)(S_c - \beta G - c_c - F) + (1-y)z(S_C + \alpha E - c_c + P_l) + (1-y)(1-z)(S_C - \beta G - c_c + P_c) \tag{5-2}$$

$$U_{c2} = yz(\alpha E - F) + y(1-z)(-F - \beta G) + (1-y)z\alpha E + (1-y)(1-z)(-\beta G) \tag{5-3}$$

$$\overline{U_c} = xU_{c1} + (1-x)U_{c2} \tag{5-4}$$

Then, the replicator dynamic equation of the central government choosing "strict supervision" strategy follows:

$$F(x) = \dot{x} = x(U_{c1} - \overline{U_c}) \tag{5-5}$$

(2) The local governments' expected payoffs of "full implementation" and "partial implementation" strategies and the average expected payoff are shown in U_{l1}, U_{l2} and $\overline{U}_l$:

$$U_{l1} = xz[S_l + F - c_l - L + (1-\alpha)E - J] + x(1-z)[S_l + F - c_l + P_d - (1-\beta)G - L] + (1-x)z[S_l + (1-\alpha)E + F - J - c_l - L] + (1-x)(1-z)[S_l + F - L + P_d - (1-\beta)G - c_l] \tag{5-6}$$

$$U_{l2} = xz[(1-\alpha)E - P_l] + x(1-z)[R - (1-\beta)G - \lambda P_c] + (1-x)z(1-\alpha)E + (1-x)(1-z)[R - (1-\beta)G] \tag{5-7}$$

$$\overline{U}_l = yU_{l1} + (1-y)U_{l2} \tag{5-8}$$

Then, the replicator dynamic equation of the local governments choosing "full implementation" strategy is as follows:

$$F(y) = \dot{y} = y(U_{l1} - \overline{U}_l) \tag{5-9}$$

(3) The developers' expected payoffs of "construct GBs" and "construct TBs" strategies and the average expected payoff are shown in U_{d1}, U_{d2} and $\overline{U_d}$:

$$U_{d1} = xy(\pi_g + J) + x(1-y){\pi_g}' + (1-x)y(\pi_g + J) + (1-x)(1-y){\pi_g}' \tag{5-10}$$

$$U_{d2} = xy(\pi_t - P_d) + x(1-y)[\pi_t{}' - R - (1-\lambda)P_c] + (1-x)y(\pi_t - P_d) + (1-x)(1-y)(\pi_t{}' - R) \tag{5-11}$$

$$\overline{U_d} = zU_{d1} + (1-z)U_{d2} \tag{5-12}$$

Then, the replicator dynamic equation of the developers choosing "construct GBs" strategy is as follows:

$$F(z) = \dot{z} = z(U_{d1} - \overline{U_d}) \tag{5-13}$$

5.3.2 Tripartite evolutionary game model

Based on Eqs. (5-5), (5-9) and (5-13), the tripartite dynamic replication equations of the GB promotion system are shown in Eq. (5-14), where the central government, local governments and developers are all considered as decision-makers. In response to individual decisions, the probability that each participant adopts its corresponding strategy varies over time. This evolutionary process is explained by the fact that stakeholders consciously modify their strategies through multiple game rounds, choosing new strategies that maximise their benefits. Thus, this study aims to identify the maximum payoffs of the central government, local governments and developers by analysing the tripartite evolutionary game's destination (e.g., the ESS). ESS stands for the strategy adopted by the majority of individuals because its advantages outweigh those of other strategies (Maynard Smith, 1974).

$$\begin{cases} \dot{x} = x(1-x)[(1-y)(P_c(1-z) + P_l z) - c_c + S_c] \\ \dot{y} = y(1-y)[F + (P_d + P_c x\lambda - R)(1-z) + (P_l x - J)z - c_l + S_l - L] \\ \dot{z} = z(1-z)\left\{\frac{2c_t - 2c_g + 2Ty + 3(J+P_d)y - (e_g - e_t)[\theta - 3\mu(e_g + e_t)] + 3[P_c x(1-\lambda) + R](1-y)}{3}\right\} \end{cases} \tag{5-14}$$

5.4 Decision-Making Behaviours of Participants

According to the stability theorem and the dynamic game theory of replication, Θ is the ESS point when the conditions of $F(\Theta^*) = 0$ and $F'(\Theta^*) < 0$ are satisfied (Chaab & Rasti-Barzoki, 2016; I.-H. Hong et al., 2016). Based on this theorem, the ESSs of the central government, local governments and developers are obtained. The different decision-making behaviours are discussed in detail as follows:

5.4.1 Decision-making behaviours of the central government

Lemma 5.1. For the central government, when $F(x) = 0$, three kinds of stable game systems are in the replicated dynamic equation: $x^* = 0, x^* = 1, y^* = \frac{P_c(1-z)+P_l z-c_c+S_c}{P_c(1-z)+P_l z}$.

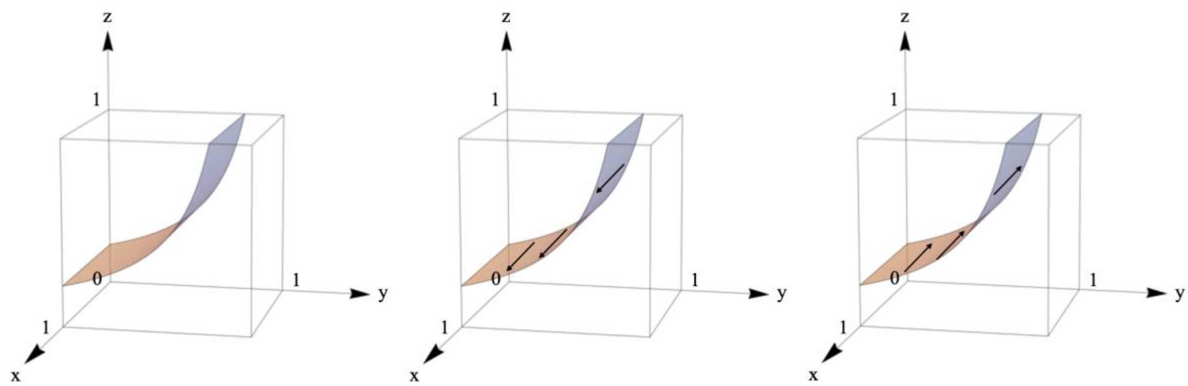
Proposition 5.1.

(1) When $y = y^* = \frac{P_c(1-z)+P_l z-c_c+S_c}{P_c(1-z)+P_l z}$, $F'(x)|_{x=0} = 0$ and $F'(x)|_{x=1} = 0$, which indicates that neither "strict supervision" nor "loose supervision" is a stable strategy for the central government.

(2) When $y < y^* = \frac{P_c(1-z)+P_l z-c_c+S_c}{P_c(1-z)+P_l z}$, $F'(x)|_{x=0} > 0$ and $F'(x)|_{x=1} < 0$, which indicates that $x^* = 1$ is the only ESS point, and the central government's "strict supervision" strategy can reach a stable state under this condition.

(3) When $y > y^* = \frac{P_c(1-z)+P_l z-c_c+S_c}{P_c(1-z)+P_l z}$, $F'(x)|_{x=0} < 0$ and $F'(x)|_{x=1} > 0$, which indicates that $x^* = 0$ is the only ESS point, and the central government chooses to "loose supervision" under this condition.

According to Proposition 5.1, the evolutionary phase diagram depicting the choices in central government actions is illustrated in Figure 5.3.



(a) $y = y^*$ (b) $y < y^*$ (c) $y > y^*$

Figure 5.3 Evolutionary phase diagram of central government behavioural choices.

Proposition 5.1 indicates that local governments with a higher probability of full implementation of GBPs, in other words, local governments that can consciously carry out GBPs implementation, would change the central government's stable strategy from strict supervision to loose supervision to save regulatory costs. By contrast, if the local governments prefer to implement partially, the central government would take strict regulation measures to avoid social and environmental losses. Moreover, the main factors affecting the supervision strategies of the central government include the penalties to local governments and collusion, the costs of strict supervision and social benefits. The construction strategy of developers would also affect the central government's supervision strategy.

Corollary 5.1.1. Developers' willingness to construct GBs does not always reduce the central government's willingness to strict supervision. It depends on the comparison between penalties of collusion and partial implementation. When the penalty of partial implementation surpasses the penalty of collusion, the more developers became willing to construct GBs, the more inclined the central government was to supervise strictly. Otherwise, when the penalty of collusion is larger than that of partial implementation, the more developers willing to construct GBs, the more inclined the central government to supervise loosely.

Proof: To discuss the factors affecting the central government's strategy, $0 < y^* = 1 + \frac{S_c - c_c}{P_c(1-z)+P_l z} < 1$ is held. Then, $S_c < c_c$ must be satisfied. Otherwise, if $y^* < 0$ or $y^* > 1$, $y^* < y$ or $y < y^*$ always holds. Analysing the influencing factors is unnecessary because the central government's strategy would not change. $\frac{dy^*}{dz} = \frac{(P_l - P_c)(c_c - S_c)}{(P_c(z-1)-P_l z)^2}$, when $P_l - P_c > 0$, $\frac{dy^*}{dz} > 0$, y^* is an increasing function with respect to z. Based on proposition 5.1, when $y < y^*$, the central government will supervise strictly. Therefore, when z goes up and y^* increases, point y will also go up. $0 < y^* = 1 + \frac{S_c - c_c}{P_c(1-z)+P_l z} < 1$, then $S_c < c_c$.

Corollary 5.1.2. The central government would be more willing to supervise strictly when social benefits or penalties rise or when supervision cost falls.

Proof: $\frac{dy^*}{dc_c} = -\frac{1}{P_c(1-z)+P_l z} < 0$, $\frac{dy^*}{dP_c} = \frac{(1-z)(c_c - S_c)}{(P_c(z-1)-P_l z)^2} > 0$, $\frac{dy^*}{dP_l} = \frac{z(c_c - S_c)}{P_c(1-z)+P_l z} > 0$, $\frac{dy^*}{dS_c} = \frac{1}{P_c(1-z)+P_l z} > 0$, y^* is a decreasing function with respect to c_c and an increasing function with respect to P_c, P_l and S_c. The rise of S_c or the decrease of c_c would lead to the rise of y^*. Based on proposition 5.1, when $y < y^*$, the central government will supervise strictly. Therefore, when y^* increases, y will also go up.

Corollary 5.1.3. When the social benefits obtained from strict supervision are greater than a certain threshold (that is, $S_c > S_c{}^* = [P_c(1-z) + P_l z](y-1) + c_c$), the central government is likely to supervise strictly.

Proof: When $S_c > S_c{}^* = [P_c(1-z) + P_l z](y-1) + c_c$, $F'(x)|_{x=0} > 0$ and $F'(x)|_{x=1} < 0$.

5.4.2 Decision-making behaviours of the local governments

Lemma 5.2. For local governments, when $F(y) = 0$, three kinds of stable game systems are used in the replicated dynamic equation: $y^* = 0$, $y^* = 1$, $x^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F}{P_c\lambda(1-z)+P_l z}$

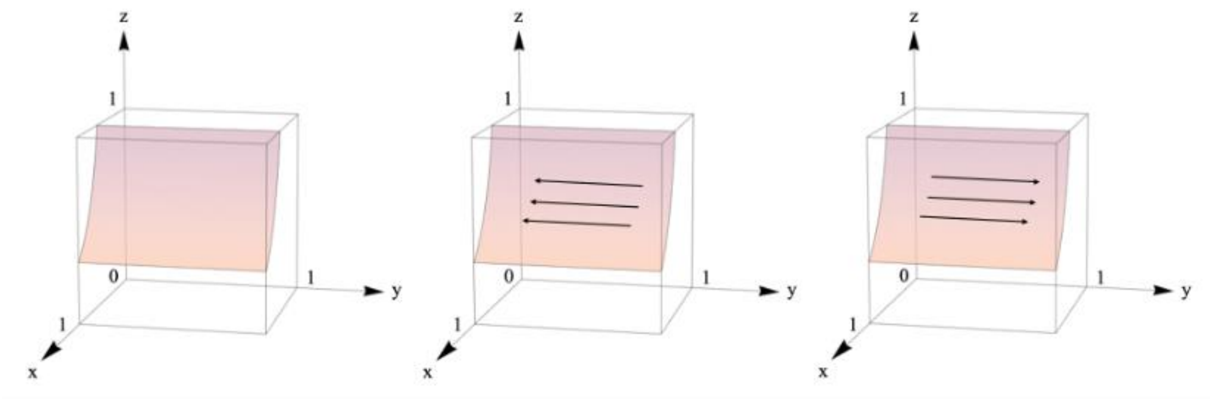
Proposition 5.2.

(1) When $x = x^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F}{P_c\lambda(1-z)+P_l z}$, $F'(y)|_{y=0} = 0$ and $F'(y)|_{y=1} = 0$, which indicates that neither "full implementation" nor "partial implementation" is a stable strategy for local governments.

(2) When $x < x^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F}{P_c\lambda(1-z)+P_l z}$, $F'(y)|_{y=0} < 0$ and $F'(y)|_{y=1} > 0$, which indicates that $y^* = 0$ is the only ESS point, and local governments choose "partial implementation" under this condition.

(3) When $x > x^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F}{P_c\lambda(1-z)+P_l z}$, $F'(y)|_{y=0} > 0$ and $F'(y)|_{y=1} < 0$, which indicates that $y^* = 1$ is the only ESS point, and local governments' "full implementation" strategy can reach a stable state under this condition.

According to Proposition 5.2, the evolutionary phase diagram depicting the choices in local governments' actions is illustrated in Figure 5.4.



(a) $x = x^*$ (b) $x < x^*$ (c) $x > x^*$

Figure 5.4 Evolutionary phase diagram of local governments' behavioural choices.

Proposition 5.2 indicates that the central government's willingness to supervise will change the stable strategy of local governments from partial implementation to full implementation and vice versa. The central government's strong regulation would prompt local governments to perform their duties actively and conduct full implementation. Otherwise, the rent-seeking behaviour would be detected with a higher probability and thus be punished. Conversely, to save regulatory costs, the speculative behaviour of local governments would lead to partial implementation because they are less likely to be detected under loose supervision. In addition to the central government's supervision strategy, the construction strategy of developers, the penalties, rent-seeking and social benefits, costs of incentive and economic losses of full implementation would also affect the implementation strategy of the local governments.

Corollary 5.2.1. Developers' willingness to construct GBs does not always lead to the local governments' higher willingness to partial implementation. A threshold λ^* exists; when the proportion of penalties paid by local governments is relatively small, local governments are more willing to implement GBPs fully as more developers are willing to construct GBs. In contrast, if the proportion is rather large, local governments are more willing to implement partially as more developers are willing to construct GBs.

Proof: To discuss the factors affecting the local governments' strategy, $0 < x^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F}{P_c\lambda(1-z)+P_lz} < 1$ is held. Then, $P_c\lambda(1-z) + P_lz > L - P_d(1-z) + R(1-z) + Jz + c_l - S_l - F > 0$ must be satisfied. Otherwise, if $x^* < 0$ or $x^* > 1$, $x^* < x$ or $x < x^*$ always holds. Analysing the influencing factors is unnecessary because the local governments' strategy would not change. $\frac{\partial x^*}{\partial z} = \frac{(F+P_d-L-R-c_l+S_L)P_l+\lambda P_c(J+L+c_l-S_L-F)}{(P_lz+P_c\lambda(1-z))^2}$, when $\lambda > \lambda^* = \frac{(L+R+c_l-S_L-P_d-F)P_l}{(J+L+c_l-S_L-F)P_c}$, $\frac{dx^*}{dz} > 0$, x^* is an increasing function with respect to z. Based on proposition 5.2, when $x < x^*$, the local governments will implement partially. Therefore, when z goes up and x^* increases, point x will also go up. $0 < x^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F}{P_c\lambda(1-z)+P_lz} < 1$, then $P_c\lambda(1-z) + P_lz > L - P_d(1-z) + R(1-z) + Jz + c_l - S_l - F > 0$.

Corollary 5.2.2. Local governments are more inclined to implement fully when the penalties, rewards to local governments, the proportion of penalties paid by local governments and social benefits increase. On the contrary, local governments are more inclined to partial implementation when the cost and economic losses of full implementation, rent-seeking benefits and rewards to developers increase.

Proof: $\frac{dx^*}{dc_l} = \frac{dx^*}{dL} = \frac{1}{P_c\lambda(1-z)+P_lz} > 0$, $\frac{dx^*}{dR} = \frac{1-z}{P_c\lambda(1-z)+P_lz} > 0$, $\frac{dx^*}{dJ} = \frac{z}{P_c\lambda(1-z)+P_lz} > 0$, $\frac{dx^*}{dF} = \frac{dx^*}{dS_l} = -\frac{1}{P_c\lambda(1-z)+P_lz} < 0$, $\frac{dx^*}{d\lambda} = -\frac{P_c(1-z)[L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F]}{\left(P_lz+P_c\lambda(1-z)\right)^2} < 0$, $\frac{dx^*}{dP_d} = -\frac{1-z}{P_c\lambda(1-z)+P_lz} < 0$, $\frac{dx^*}{dP_c} = -\frac{\lambda(1-z)[L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F]}{\left(P_lz+P_c\lambda(1-z)\right)^2} < 0$, $\frac{dx^*}{dP_l} =$

$-\frac{z[L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F]}{(P_l z+P_c\lambda(1-z))^2} < 0$, x^* is a decreasing function with respect to λ, P_d, P_c, P_l, S_l and F, and an increasing function with respect to L, c_l, R and J. The rise of L, c_l, R and J or the decrease of λ, P_d, P_c, P_l, S_l and F would lead to the rise of x^*. Based on proposition 5.2, when $x < x^*$, local governments will implement partially. Therefore, when x^* increases, point x will also go up.

Corollary 5.2.3. When penalties of partial implementation are greater than a certain threshold (that is, $P_c\lambda > P_c\lambda^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F-P_l zx}{x(1-z)}$, $P_l > P_l{}^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F-P_c\lambda(1-z)x}{z}$), local governments choose to implement fully.

Proof: When $P_c\lambda > P_c\lambda^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F-P_l zx}{x(1-z)}$, $P_l > P_l{}^* = \frac{L-P_d(1-z)+R(1-z)+Jz+c_l-S_l-F-P_c\lambda(1-z)x}{z}$, $F'(y)|_{y=1} < 0$ and $F'(y)|_{y=1} < 0$.

5.4.3 Decision-making behaviours of the developers

Lemma 5.3. For developers, when $F(z) = 0$, three kinds of stable game systems are used in the replicated dynamic equation: $z^* = 0$, $z^* = 1$, $x^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3(J+P_d)y-(e_g-e_t)\theta+3\mu(e_g{}^2-e_t{}^2)}{3P_c(1-\lambda)(1-y)}$.

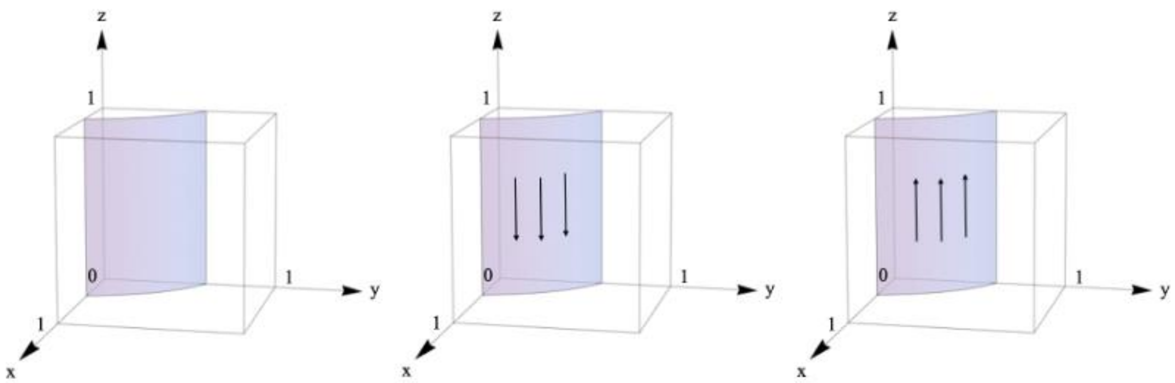
Proposition 5.3.

(1) When $x = x^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3(J+P_d)y-(e_g-e_t)\theta+3\mu(e_g{}^2-e_t{}^2)}{3P_c(1-\lambda)(1-y)}$, $F'(z)|_{z=0} = 0$ and $F'(z)|_{z=1} = 0$, which indicates that neither "construct GBs" nor "construct TBs" is a stable strategy for developers.

(2) When $x < x^* = \frac{2(c_g - c_t) - 3R(1-y) - 2Ty - 3(J+P_d)y - (e_g - e_t)\theta + 3\mu(e_g{}^2 - e_t{}^2)}{3P_c(1-\lambda)(1-y)}$, $F'(z)|_{z=0} < 0$ and $F'(z)|_{z=1} > 0$, which indicates that $z^* = 0$ is the only ESS point, and developers choose to "construct TBs" under this condition.

(3) When $x > x^* = \frac{2(c_g - c_t) - 3R(1-y) - 2Ty - 3(J+P_d)y - (e_g - e_t)\theta + 3\mu(e_g{}^2 - e_t{}^2)}{3P_c(1-\lambda)(1-y)}$, $F'(z)|_{z=0} > 0$ and $F'(z)|_{z=1} < 0$, which indicates that $z^* = 1$ is the only ESS point, and developers' "construct GBs" strategy can reach a stable state under this condition.

According to Proposition 5.3, the evolutionary phase diagram depicting the choices in developers' actions is illustrated in Figure 5.5.



(a) $x = x^*$ (b) $x < x^*$ (c) $x > x^*$

Figure 5.5 Evolutionary phase diagram of developers' behavioural choices.

From Proposition 5.3, the increase in the probability of the central government's strict supervision will change the developers' stable strategy from developing TBs to GBs. Similarly, the less likely the central government is willing to supervise strictly, the more developers will tend to construct TBs. Therefore, the central government's willingness to supervise is essential for the development of GB. Moreover, the main factors affecting developers' construction strategy contain the cost and greenness gaps between GB and TB, penalties from central and local governments, bribery costs, green preference payment coefficient and rewards to developers and consumers.

Corollary 5.3.1. Full implementation of local governments does not always lead to developers' higher willingness to construct GBs. A threshold of penalty exists; when the penalty is relatively large, more developers are willing to construct GBs as local governments' willingness to full implementation increases. In contrast, if the proportion is relatively small, more developers are willing to construct TBs as local governments' willingness to full implementation increases.

Proof: To discuss the factors affecting the developers' strategy, $0 < x^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3(J+P_d)y-(e_g-e_t)\theta+3\mu(e_g{}^2-e_t{}^2)}{3P_c(1-\lambda)(1-y)} < 1$ is held. Then, $3P_c(1-\lambda)(1-y) > 2(c_g-c_t)-3R(1-y)-2Ty-3(J+P_d)y-(e_g-e_t)\theta+3\mu(e_g{}^2-e_t{}^2) > 0$ must be satisfied. Otherwise, if $x^* < 0$ or $x^* > 1$, $x^* < x$ or $x < x^*$ always holds. Analysing the influencing factors is unnecessary because the developers' strategy would not change. $\frac{dx^*}{dy} = \frac{2(c_g-c_t)-3J-3P_d-2T-(e_g-e_t)\theta+3\mu(e_g{}^2-e_t{}^2)}{3P_c(1-\lambda)(1-y)^2}$, when $P_d < P_d{}^* = \frac{2(c_g-c_t)-3J-2T-(e_g-e_t)\theta+3\mu(e_g{}^2-e_t{}^2)}{3}$, $\frac{dx^*}{dy} > 0$, x^* is an increasing function with respect to y. Based on proposition 5.3, when $x < x^*$, developers will construct TBs. Therefore, when y goes up and x^* increases, point x will also go up.

Corollary 5.3.2. The influence of buildings' greenness on developers' willingness to construct GBs depends on the comparison between R&D cost and green preference payment coefficient. When customers' willingness to pay for GBs is higher than a certain R&D cost, the higher greenness of GBs or lower greenness of TBs, developers are more willing to construct GBs. When customers' willingness to pay for GBs is low, higher greenness of GBs or lower greenness of TBs will decrease the developers' willingness to construct GBs.

Proof: $\frac{dx^*}{de_g} = \frac{6\mu e_g - \theta}{3P_c(1-\lambda)(1-y)}$, $\frac{dx^*}{de_t} = \frac{\theta - 6\mu e_t}{3P_c(1-\lambda)(1-y)}$, when $6\mu e_g > \theta$ and $6\mu e_t > \theta$, x^* is a decreasing function with respect to e_t, and an increasing function with respect to e_g. The rise of e_g or the decrease of e_t would lead to the rise of x^*. Based on proposition 5.3, when $x < x^*$, developers will construct TBs. Therefore, when x^* increases, point x will also go up. Vice versa.

Corollary 5.3.3. Developers are more inclined to construct GBs when bribery costs, rewards, green preference payment coefficient, penalty and greenness difference between GB and TB rise or the cost difference between GB and TB, the proportion of penalties paid by local governments and R&D cost coefficient falls.

Proof: $\frac{dx^*}{d(c_g - c_t)} = \frac{2}{3P_c(1-\lambda)(1-y)} > 0$, $\frac{dx^*}{d\mu} = \frac{{e_g}^2 - {e_t}^2}{P_c(1-\lambda)(1-y)} > 0$, $\frac{dx^*}{d\lambda} = \frac{2(c_g - c_t) - 3R(1-y) - 2Ty - 3(J+P_d)y - (e_g - e_t)\theta}{3{P_c}^2(1-\lambda)(1-y)} > 0$, $\frac{dx^*}{dR} = -\frac{(1-y)}{P_c(1-\lambda)(1-y)} < 0$, $\frac{dx^*}{dJ} = -\frac{y}{P_c(1-\lambda)(1-y)} < 0$, $\frac{dx^*}{d\theta} = -\frac{e_g - e_t}{3P_c(1-\lambda)(1-y)} < 0$, $\frac{dx^*}{dP_d} = -\frac{y}{P_c(1-\lambda)(1-y)} < 0$, $\frac{dx^*}{dP_c} = -\frac{2(c_g - c_t) - 3R(1-y) - 2Ty - 3(J+P_d)y - (e_g - e_t)\theta}{3{P_c}^2(1-\lambda)(1-y)} < 0$, $\frac{dx^*}{d(e_g - e_t)} = -\frac{\theta}{P_c(1-\lambda)(1-y)} < 0$, $\frac{dx^*}{dT} = -\frac{2y}{P_c(1-\lambda)(1-y)} < 0$ x^* is a decreasing function with respect to R, J, θ, P_d, P_c and T, and an increasing function with respect to $(c_g - c_t)$, λ and μ. The rise of $(c_g - c_t)$, λ and μ or the decrease of R, J, θ, P_d, P_c and T would lead to the rise of x^*. Based on proposition 5.3, when $x < x^*$, developers will construct TBs. Therefore, when x^* increases, point x will also go up.

Corollary 5.3.4. When penalty or reward is greater than a certain threshold (that is, $P_c(1-\lambda) > P_c(1-\lambda)^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3(J+P_d)y-(e_g-e_t)\theta}{3P_c x(1-y)}$, $P_d > P_d{}^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3Jy-(e_g-e_t)\theta-3P_c(1-\lambda)(1-y)x}{3y}$, $J > J^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3P_d y-(e_g-e_t)\theta-3P_c(1-\lambda)(1-y)x}{3y}$), it can ensure that developers choose to construct GBs.

Proof: When $P_c(1-\lambda) > P_c(1-\lambda)^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3(J+P_d)y-(e_g-e_t)\theta}{3P_c x(1-y)}$, $P_d > P_d{}^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3Jy-(e_g-e_t)\theta-3P_c(1-\lambda)(1-y)x}{3y}$, $J > J^* = \frac{2(c_g-c_t)-3R(1-y)-2Ty-3P_d y-(e_g-e_t)\theta-3P_c(1-\lambda)(1-y)x}{3y}$, $F'(z)|_{z=0} > 0$ and $F'(z)|_{z=1} < 0$.

5.4.4 Summary of factors influencing the behaviour of the three parties

For a more precise understanding, the above findings are summarised in Table 5.2. In conclusion, the three main stakeholders' strategy choices in the GB promotion system are all influenced by default penalty for collusion and the strategies of others. Environmental benefits, as well as governance costs, do not affect central or local governments' strategies.

Table 5.2 Parameters' influence on the strategy choice of main stakeholders.

Parameters	x	y	z	c_c	S_c	P_l	P_c	P_d	λ	S_l	F
x	/	–	+ or –[1]	–	+	+	+	/	/	/	/
y	+	/	– or +[2]	/	/	+	+	+	+	+	+

z	+	+ or –[3]	/	/	/	/	+	+	–	/	/

Parameters	L	c_l	R	J	θ	T	μ	e_g	e_t	$c_g - c_t$
x	/	/	/	/	/	/	/	/	/	/
y	–	–	–	–	/	/	/	/	/	/
z	/	/	+	+	+	+	–	– or +[4]	+ or –[5]	–

Note: +: positive; –: negative; /: no influence; 1: + when $P_l > P_c$ and – when $P_l < P_c$; 2: – when $\lambda > \lambda^*$ and + when $\lambda < \lambda^*$; 3: + when $P_d > {P_d}^*$ and – when $P_d < {P_d}^*$; 4: – when $6\mu e_g > \theta$ and + when $6\mu e_g < \theta$; 5: + when $6\mu e_t > \theta$ and – when $6\mu e_t < \theta$.

5.5 Stability of GB Promotion System

Whether the equilibrium points determined from replicated dynamic equations in subsection 5.4 are the GB promotion system's ESSs remains uncertain. According to Eq. (5-14), when $\begin{cases}\dot{x} = 0\\ \dot{y} = 0\\ \dot{z} = 0\end{cases}$, eight pure-strategy equilibrium points of the system can be determined: E1(0,0,0), E2(0,0,1), E3(0,1,0), E4(1,0,0), E5(1,1,0), E6 (1,0,1), E7(0,1,1) and E8(1,1,1). A mixed strategy equilibrium point E*(x*, y*, z*) may exist only 0≤ x*≤1, 0≤y*≤1, 0≤z*≤1 are satisfied. Previous studies (Md. Ahsan Habib et al., 2022; Tanimoto, 2021) have explored internal equilibria in 2-player games, providing valuable insights into the dynamics of game theory. In the context of multi-subject game, only a pure strategy Nash equilibrium can become an asymptotically stable equilibrium point ("sink") (Hewitt & Wainwright, 1993; Lyapunov, 1992; Selten, 1988). Consequently, E* is a mixed strategy Nash equilibrium, but not a "sink". This results in a non-optimal outcome for the tripartite game. Given these considerations, this study only analysed the asymptotic stability of the eight pure strategy equilibrium points. The asymptotic stability of the eight pure strategy equilibrium points can be determined by judging the eigenvalues of the Jacobian matrix of the replicated dynamic system. When all the eigenvalues of the equilibrium point are negative, the equilibrium point is stable; otherwise, it is unstable (D. Friedman, 1991; Lyapunov, 1992; Weibull, 1997).

According to Eq. (5-14), the Jacobian matrix of the tripartite evolutionary game can be described as follows:

$$J(x,y,z)=\begin{bmatrix}\frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z}\\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z}\\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z}\end{bmatrix} \tag{5-15}$$

After calculation, the eigenvalues of each pure strategy Nash equilibrium point are listed in Table 5.3, and the corresponding stability is discussed.

Table 5.3 Equilibrium point of the system and its characteristic values.

Equilibrium point	Eigenvalues			Stability	Stability conditions
	ξ_1	ξ_2	ξ_3		
E1(0,0,0)	$P_c - c_c + S_c$	$F + P_d - L - R - c_l + S_l$	$\{(e_g - e_t)[\theta - 3\mu(e_g + e_t)] - 2(c_g - c_t) + 3R\}/3$	Asymptotic stability point	①$P_c + S_c < c_c$ ②$F + P_d + S_l < R + c_l + L$ ③$\theta(e_g - e_t) + 3R < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$
E2(0,0,1)	$P_l - c_c + S_c$	$F + S_l - J - L - c_l$	$\{2(c_g - c_t) - 3R - (e_g - e_t)[\theta - 3\mu(e_g + e_t)]\}/3$	Asymptotic stability point	①$P_l + S_c < c_c$ ②$F + S_l < J + L + c_l$ ③$\theta(e_g - e_t) + 3R > 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$
E3(0,1,0)	$S_c - c_c$	$L - F - P_d + R + c_l - S_l$	$\{(e_g - e_t)[\theta - 3\mu(e_g + e_t)] - 2(c_g - c_t) + 3(J + P_d) + 2T\}/3$	Asymptotic stability point	①$S_c < c_c$ ②$L + R + c_l < P_d + S_l + F$ ③ $\theta(e_g - e_t) + 3(J + P_d) + 2T < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$
E4(1,0,0)	$c_c - S_c - P_c$	$F + S_l - L + P_d - R + P_c\lambda - c_l$	$\{(e_g - e_t)[\theta - 3\mu(e_g + e_t)] - 2(c_g -$	Asymptotic stability point	①$P_c + S_c > c_c$ ②$F + S_l + P_d + P_c\lambda < L + R + c_l$

			$c_t) + 3P_c(1-\lambda) + 3R\}/3$		③$\theta(e_g - e_t) + 3P_c(1-\lambda) + 3R < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$
E5(1,1,0)	$c_c - S_c$	$L - F - P_d + R - P_c\lambda + c_l - S_l$	$\{(e_g - e_t)[\theta - 3\mu(e_g + e_t)] - 2(c_g - c_t) + 3(J + P_d) + 2T\}/3$	Asymptotic stability point	①$c_c < S_c$ ②$F + S_l + P_d + P_c\lambda > L + R + c_l$ ③ $\theta(e_g - e_t) + 3(J + P_d) + 2T < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$
E6(1,0,1)	$c_c - S_c - P_l$	$F + P_l - c_l + S_l - J - L$	$\{2(c_g - c_t) - 3R - (e_g - e_t)[\theta - 3\mu(e_g + e_t)] - 3P_c(1-\lambda)\}/3$	Asymptotic stability point	①$P_l + S_c > c_c$ ②$F + P_l + S_l < J + L + c_l$ ③$\theta(e_g - e_t) + 3P_c(1-\lambda) + 3R > 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$
E7(0,1,1)	$S_c - c_c$	$J - F + L + c_l - S_l$	$\{2(c_g - c_t) - 3(J + P_d) - 2T - (e_g - e_t)[\theta - 3\mu(e_g + e_t)]\}/3$	Asymptotic stability point	①$c_c > S_c$ ②$F + S_l > J + L + c_l$ ③$2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$
E8(1,1,1)	$c_c - S_c$	$J - F + L - P_l + c_l - S_l$	$\{2(c_g - c_t) - 3(J + P_d) - 2T - (e_g - e_t)[\theta - 3\mu(e_g + e_t)]\}/3$	Asymptotic stability point	①$c_c < S_c$ ②$F + P_l + S_l > J + L + c_l$ ③$2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$

Table 5.3 shows that eight equilibrium points can evolve to an asymptotic stable state if they meet their corresponding conditions. The specific analysis is as follows:

Proposition 5.4.

When $P_c + S_c < c_c$, $F + P_d + S_l < R + c_l + L$ and $\theta(e_g - e_t) + 3R < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$ are simultaneously satisfied, the equilibrium point E1(0,0,0) becomes the ESS of the GB promotion system. This implies: when (1) the social benefits brought by strict supervision and the collusion penalty received by the central government are less than the cost of strict supervision; (2) the combined benefits of collusion between local governments and developers, the costs incurred in fully implementing the policy, and the economic losses caused are greater than the sum of the rewards from the central government for full implementation, social benefits and penalties to developers; (3) when the additional costs incurred by developers for constructing GBs exceed the rent-seeking costs and the consumer preference for GBs, the behaviours of the three parties ultimately stabilise as follows: the central government loosens supervision, local governments partially implement GBPs and developers construct TBs.

Proposition 5.4 indicates that high regulatory costs will hinder the central government from enforcing strict supervision. If the benefits of collusion are sufficiently attractive to local governments while the benefits of full GBP implementation are insufficient, and if the costs of GBs are excessively high, developers will prefer to bear rent-seeking costs rather than develop GBs. This corresponds to real-world phenomena of government and market failures (such as in some central and western cities of China), where the entire GB promotion system is ineffective.

Proposition 5.5.

When $P_c + S_c > c_c$, $F + S_l + P_d + P_c\lambda < L + R + c_l$ and $\theta(e_g - e_t) + 3P_c(1-\lambda) + 3R < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$ are simultaneously satisfied, the equilibrium point E4(1,0,0) is the ESS of the GB promotion system. This implies: when (1) the social benefits brought by strict supervision and the collusion penalty received by the central government are greater than the cost of strict supervision; (2) the combined benefits of collusion between local governments and developers, the costs incurred in fully implementing GBPs, and the economic losses caused are greater than the sum of the rewards from the central government for full implementation, social benefits, collusion penalties and penalties to developers; (3) when the additional costs incurred by developers for constructing GBs are greater than the rent-seeking costs, consumer preference for GBs and collusion penalties, the behaviours of the three parties ultimately stabilise as follows: the central government strictly supervises, local governments partially implement GBPs and developers construct TBs.

Proposition 5.5 indicates that the central government's strict supervision has not been effective, and both local governments and developers are negative towards GB promotion. If the penalty benefits and social benefits gained from strict supervision by the central government exceed the costs borne, this implies that, in the face of environmental degradation and social pressure, the central government recognises the importance of regulating GB and promotes GB through regulatory measures. However, even if punished by the central government, local governments will not fully implement GBPs if their economic burden and rent-seeking benefits are relatively high. At this point, if consumer willingness to purchase GB is low, and developers' GB costs exceed the central government's penalties and rent-seeking costs, developers will still choose to develop TBs. One reason for this situation may be the insufficient penalties for collusion, which prompt local governments and developers to choose collusion as a strategy in the face of high promotion costs.

Proposition 5.6.

When $c_c < S_c$, $F + S_l + P_d + P_c\lambda > L + R + c_l$ and $\theta(e_g - e_t) + 3(J + P_d) + 2T < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$ are simultaneously satisfied, the equilibrium point E5(1,1,0) is the ESS of the GB promotion system. This implies: when (1) the social benefits brought by strict supervision are greater than the cost of strict supervision; (2) the combined benefits of collusion between local governments and developers, the costs incurred in fully implementing the policy, and the economic losses caused are less than the sum of the rewards from the central government for full implementation, social benefits, collusion penalties and penalties to developers; (3) when the additional costs incurred by developers for constructing GBs are greater than the rewards, consumer preference for GBs, and penalties for constructing TBs, the behaviours of the three parties ultimately stabilise as follows: the central government strictly supervises, local governments fully implement GBPs and developers construct TBs.

Proposition 5.6 indicates a failure in government policy measures in GB promotion. Despite active participation by both central and local governments in promoting GB, developers still do not develop GBs. If central and local governments actively promote GB, they can achieve more social benefits. Meanwhile, the central government can increase collusion penalties and rewards for full implementation, reducing the incentive for local government–developer collusion and encouraging local governments to fully implement GBPs under strict central supervision through incentive mechanisms. However, due to the high costs of GB, insufficient policy intensity (such as inadequate rewards and penalties) and low market enthusiasm, developers are still unwilling to bear the high costs of constructing GB, despite the existence of reward and penalty measures.

Proposition 5.7.

When $P_l + S_c > c_c$, $F + P_l + S_l < J + L + c_l$ and $\theta(e_g - e_t) + 3P_c(1 - \lambda) + 3R > 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$ are simultaneously satisfied, the equilibrium point E6(1,0,1) is the ESS of the GB promotion system. This implies: (1) the combined social benefits and penalties to local governments brought by strict supervision exceed the costs of strict supervision; (2) the costs incurred by local governments in fully implementing the policy (including implementation costs and rewards to developers) and the resulting economic losses are greater than the combined rewards from the central government for full implementation, social benefits and penalties; (3) the additional costs incurred by developers for constructing GBs are less than the combined costs of rent-seeking, consumer preference for GBs and penalties for collusion. Consequently, the behaviours of the three parties ultimately stabilise as follows: the central government strictly supervises, local governments partially implement GBPs and developers construct GBs.

Proposition 5.7 indicates that even if the central government and developers are actively involved in promoting GBs, local governments may not actively participate. If strict supervision by the central government yields substantial social benefits, and the costs for developers to construct GBs do not exceed the penalties for collusion and rent-seeking, and consumer preference for GBs increases, the behaviours of the central government and developers will stabilise at "strict supervision" and "construction of GBs," respectively. However, from the perspective of local governments, the economic losses associated with "full implementation" are substantial, and the rewards and penalties from the central government are insufficient. Therefore, they opt for partial implementation of GBPs. Additionally, if the penalty for collusion imposed by the central government is sufficiently high, developers will choose to construct GBs even if local governments do not fully implement GBPs.

Proposition 5.8.

When $c_c > S_c$, $F + S_l > J + L + c_l$ and $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ are simultaneously satisfied, the equilibrium point E7(0,1,1) is the ESS of the GB promotion system. This implies that: (1) the social benefits brought by strict supervision from the central government are less than the costs of strict supervision; (2) the total benefits for local governments when fully implementing the policy (including rewards from the central government and social benefits) exceed the combined costs (including implementation costs and rewards to developers) and economic losses; (3) the additional costs incurred by developers for constructing GBs are less than the combined rewards (including rewards to developers and consumers), consumer preference for GBs, and penalty for constructing TBs. Consequently, the behaviours of the three parties ultimately stabilise as follows: the central government loosens supervision, local governments fully implement GBPs and developers construct GBs.

Proposition 5.8 indicates that even without strict supervision from the central government, local governments and developers will voluntarily promote GBs. If the costs of strict supervision for the central government exceed the social benefits, the central government will choose to loosen supervision to save on supervision costs. If the costs of full implementation for local governments are relatively low and do not result in significant economic losses while yielding substantial social benefits, local governments will opt for full implementation of GBPs. Developers will actively construct GBs if the costs of constructing GBs are not high and local governments provide significant rewards and penalties, along with a high level of market enthusiasm. This scenario aligns with the reality in some eastern cities of China.

Proposition 5.9.

When $c_c > S_c$, $L + R + c_l < P_d + S_l + F$ and $\theta(e_g - e_t) + 3(J + P_d) + 2T < 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$ are simultaneously satisfied, the equilibrium point E3(0,1,0) is the ESS of the GB promotion system. This implies that: (1) the social benefits brought by strict supervision from the central government are less than the costs of strict supervision; (2) the total benefits for local governments when fully implementing the policy (including rewards from the central government, social benefits and penalty to developers) exceed the combined costs (including implementation costs and rewards to developers) and economic losses; (3) the additional costs incurred by developers for constructing GBs are greater than the combined rewards (including rewards to developers and consumers), consumer preference for GBs and penalty for constructing TBs. Consequently, the behaviours of the three parties ultimately stabilise as follows: the central government loosens supervision, local governments fully implement GBPs and developers construct TBs.

Unlike Proposition 5.8, Proposition 5.9 indicates that developers will not construct GBs. In this case, the central government loosens supervision while local governments fully implement GBPs. It can be observed that in this scenario, the high costs of constructing GBs, insufficient rewards and penalties provided by local governments, and low market enthusiasm result in developers lacking the motivation to construct GBs. However, if the penalty for developers is increased, the ESS conditions of Proposition 5.8 can be achieved, prompting developers to choose the construction of GBs.

Proposition 5.10.

When $P_l + S_c < c_c$, $F + S_l < J + L + c_l$ and $\theta(e_g - e_t) + 3R > 2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2)$ are simultaneously satisfied, the equilibrium point E2(0,0,1) is the ESS of the GB promotion system. This implies that: (1) the combined social benefits and penalties to local governments brought by strict supervision are less than the costs of strict supervision; (2) the total benefits for local governments when fully implementing the policy (including rewards from the central government and social benefits) are less than the combined costs (including implementation costs and rewards to developers) and economic losses; (3) the additional costs incurred by developers for constructing GBs are less than the combined consumer preference for GBs and rent-seeking costs. Consequently, the behaviours of the three parties ultimately stabilise as follows: the central government loosens supervision, local governments partially implement GBPs and developers construct GBs.

Proposition 5.10 suggests that in the absence of strong government intervention, developers spontaneously construct GBs driven by market forces. In this scenario, the implementation costs for both central and local governments are high. To save costs, they opt to loosen supervision and partially implement the policies. However, due to high rent-seeking costs and consumer preferences for GBs, developers are still motivated to construct GBs actively.

Proposition 5.11.

When $c_c < S_c$, $F + P_l + S_l > J + L + c_l$ and $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ are simultaneously satisfied, the equilibrium point E8(1,1,1) is the ESS of the GB promotion system. This implies that: (1) the social benefits brought by strict supervision from the central government are greater than the costs of strict supervision; (2) the costs incurred by local governments in fully implementing the policy (including implementation costs and rewards to developers) and the resulting economic losses are less than the combined rewards from the central government for full implementation, social benefits and penalty; (3) the additional costs incurred by developers for constructing GBs are less than the combined rewards (including rewards to developers and consumers), consumer preference for GBs and penalty for constructing TBs. Consequently, the behaviours of the three parties ultimately stabilise as follows: the central government strictly supervises, local governments fully implement GBPs and developers construct GBs.

Proposition 5.11 indicates that all three parties actively engage in promoting GBs, achieving a synergistic promotion of GBs. In this scenario, both central and local governments gain substantial social benefits, while the costs and economic losses of full implementation are relatively low. Additionally, both levels of government provide adequate rewards and penalties. Furthermore, the construction costs for developers are low and market enthusiasm is high, which further stimulates GB development.

5.6 Numerical Analysis and Discussion

Due to the limited information within the GB promotion system, stakeholders cannot accurately predict the behaviour patterns of other participants at the initial stage of their interactions. This implies that stakeholders might not be able to make optimal decisions at the beginning and need to continuously learn and adjust their behaviours based on external feedback, which prolongs the time required for the system to reach a stable equilibrium. Different factors result in the formation of various evolutionary paths.

Given the difficulty of obtaining empirical data in a short period, this section employs MATLAB for numerical simulation to visually depict the behavioural interactions and evolutionary paths of different stakeholders within the GB promotion system under MLG. The aim is to understand how various parameters affect the system's evolutionary outcomes. As previously mentioned, GBs in China are still in the developmental stage, and the government plays an irreplaceable role in their promotion. Considering the discussions in Chapter 4 and the regional developmental imbalances in China's GB promotion, the equilibrium point E8(1,1,1) is identified as an ideal state at the current stage. At this point, the central government opts for strict supervision, local governments fully implement GBPs and developers choose to construct GBs. This scenario signifies that the central government's GBPs are actively and effectively executed, achieving a synergistic promotion of GBs. In this environment, "strict supervision", "full implementation" and "construct GBs" are regarded as the chosen behaviours of the respective stakeholders in promoting GBs. Hence, this section focuses on simulating and analysing this ideal equilibrium point E8(1,1,1) to deepen the understanding.

It is noted that the advantage of numerical simulation lies in effectively depicting the internal laws of the changes rather than how real it is (M. Wang et al., 2021). In this regard, considering the lack of first-hand data, this study refers to previous studies (L. He & Chen, 2021; K. Jiang et al., 2019; Y. Jiang et al., 2022) and combines insights from expert interviews to preliminarily assign the following values to each parameter: $S_c = 6$, $F = 3$, $J = 0.4$, $S_l = 2.7$, $L = 1$, $P_c = 5$, $\lambda = 0.6$, $P_d = 1.5$, $P_l = 2.5$, $c_c = 4$, $c_l = 6$, $R = 3$, $c_g = 7$, $c_t = 2$, $e_g = 0.9$, $e_t = 0.4$, $\mu = 2$, $\theta = 16$, $T = 0.4$. All these values satisfy the model assumptions and stability conditions for E8(1,1,1). Additionally, the initial probability for each of the three parties is set at 0.5.

5.6.1 Impact of initial probabilities

As discovered in Section 5.4, different initial intentions of the three parties will affect their strategies and evolutionary paths. According to Qiao et al. (2022), 0.2, 0.5 and 0.9 are selected as the initial probabilities and deemed low, medium and high intensity, respectively.

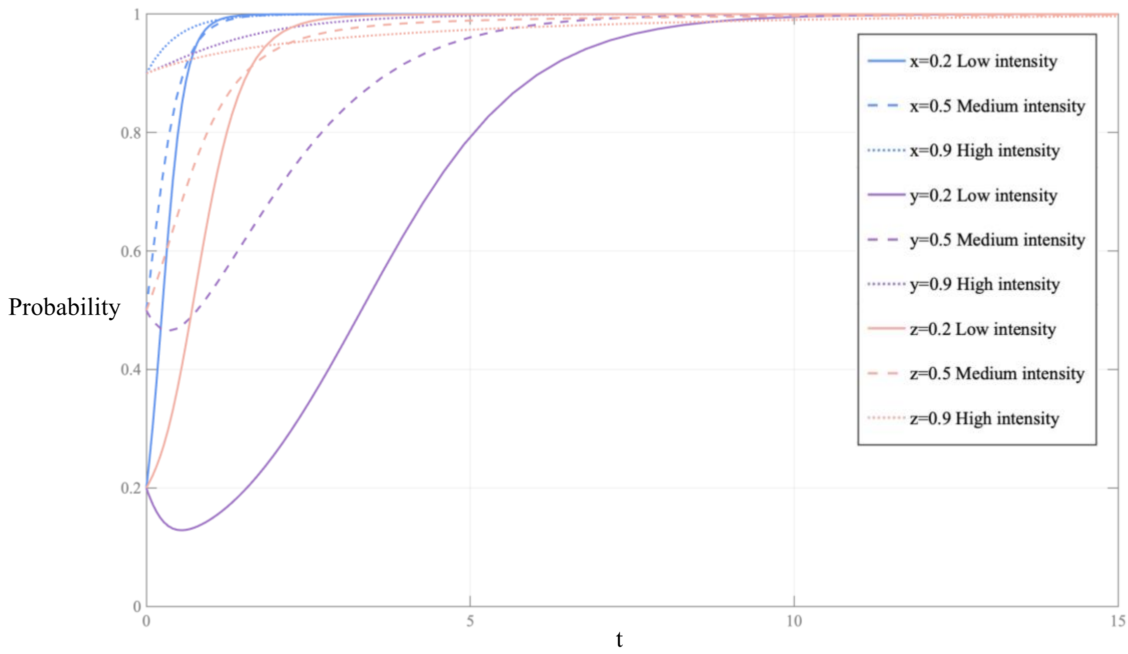


Figure 5.6 Evolutionary paths of the three parties given different initial probabilities.

Figure 5.6 shows the evolutionaty paths under the different initial intentions, that is $x = y = z = 0.2$ (low intensity), $x = y = z = 0.5$ (medium intensity) and $x = y = z = 0.9$ (high intensity). The evolutionary speed and path show significant differences under the different initial intentions.

Observation 5.1. The central government plays a leading role in promoting GB.

From the evolutionary order of stable strategies shown in Figure 5.6, the central government is the fastest to reach the equilibrium point despite different initial intentions. In other words, in an environment with asymmetric information, the central government converges to "strict supervision" the quickest, signalling strict oversight and ensuring the promotion of GBs through policy measures. Combining Propositions 5.2 and 5.3, the central government's commitment to strict supervision will prompt local governments to shift their stable strategy from "partial implementation" to "full implementation" and developers to switch from constructing "TBs" to "GBs". This underscores that the central government's determination to develop GBs directly influences the success or failure of GB promotion in China. Furthermore, the lower the overall willingness to promote GBs, the shorter the time the central government takes to reach the equilibrium point. This indicates that when all stakeholders are reluctant to promote GBs, the central government must quickly implement strict supervision to play its leading role.

5.6.2 Impact of costs

Based on the aforementioned parameter values, this subsection examines the impact of costs by varying the values of c_l and c_g.

5.6.2.1 Impact of local governments' full implementation costs

From Figure 5.7, as the full implementation costs increase, the stable point of the GB promotion system shifts from E8(1,1,1) to E6(1,0,1).

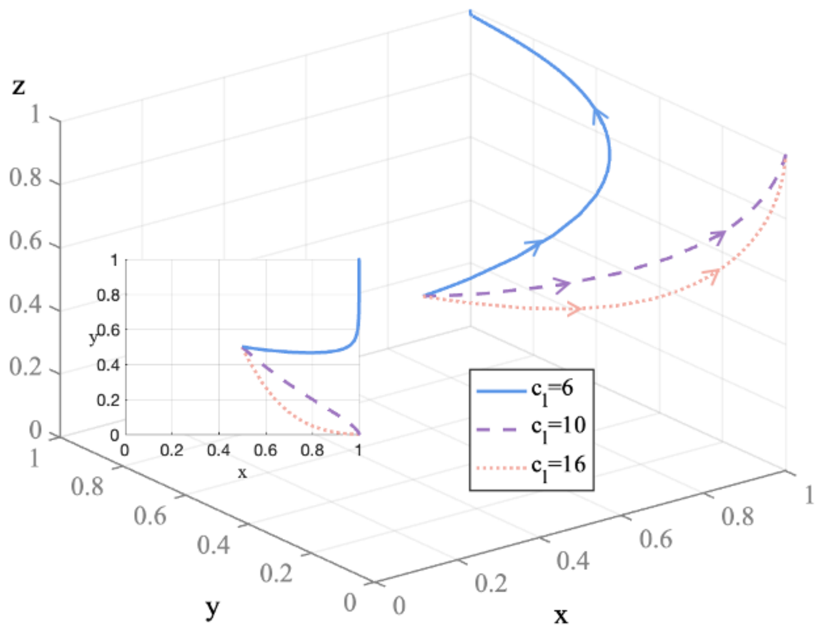


Figure 5.7 Evolutionary paths of the three parties given different local governments' full implementation costs.

Observation 5.2. High full implementation costs hinder local governments' full implementation of GBPs.

Figure 5.7 indicates that as c_l increases, local governments, despite facing penalties from the central government, will shift from "full implementation" to "partial implementation". The theoretical model in this chapter explains a key finding from Chapter 4, which highlights regional differences in implementing GBPs in China. Specifically, due to varying implementation costs, different local governments make different choices when implementing GBPs. Local governments with better economic development and stronger administrative capabilities will actively respond to the central government's call and fully implement political tasks. In contrast, underdeveloped regions, due to limited resources, can only selectively implement policies to reduce financial burdens. As discussed in Section 5.5, when the condition $F + P_l + S_l > J + L + c_l$ is met, local governments' behaviour will converge to "full implementation". Therefore, when local governments' "full implementation" costs are too high, the central government can guide local governments' behaviour through reasonable incentive mechanisms.

5.6.2.2 Impact of developers' GB costs

From Figure 5.8, as the GB costs increase, the stable point of the GB promotion system shifts from E8(1,1,1) to E4(1,1,0).

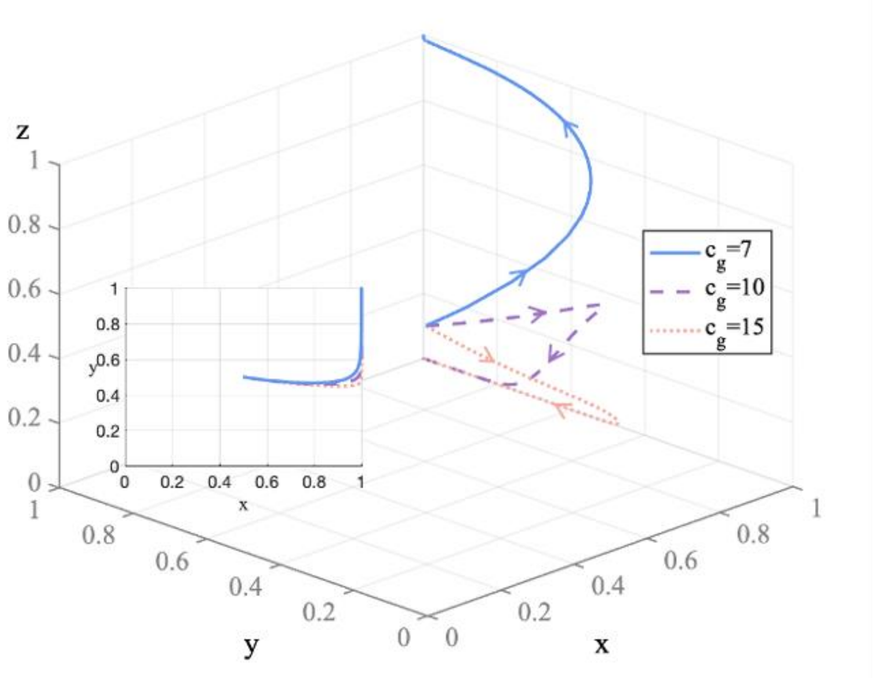


Figure 5.8 Evolutionary paths of the three parties given different developers' GB costs.

Observation 5.3. High costs of GBs hinder developers from constructing them.

As shown in Figure 8, as c_g increases, developers shift from constructing "GBs" to "TBs". The higher the GB cost, the quicker developers tend towards "TBs". Even when facing penalties from the government, developers will still choose to construct TBs due to cost pressures. Cost has always been one of the key factors constraining the promotion of GBs (Darko & Chan, 2017). Therefore, to achieve the ideal state, as discussed in Section 5.5, the condition $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ needs to be met. When c_g is too high, the role of incentive mechanisms becomes particularly important, and increasing rewards and penalties helps to achieve the ideal equilibrium.

5.6.3 Impact of government rewards

Based on the parameter values set above, this subsection analyses the impact of government incentives by respectively changing the value of J, T and F.

5.6.3.1 Impact of rewards to developers

Figure 5.9 shows the evolutionary paths of the three parties given different J. In the absence of rewards for developers, the GB promotion system becomes unstable. However, as rewards increase, the system gradually stabilises, with the stable point shifting from E8(1,1,1) to E6(1,0,1).

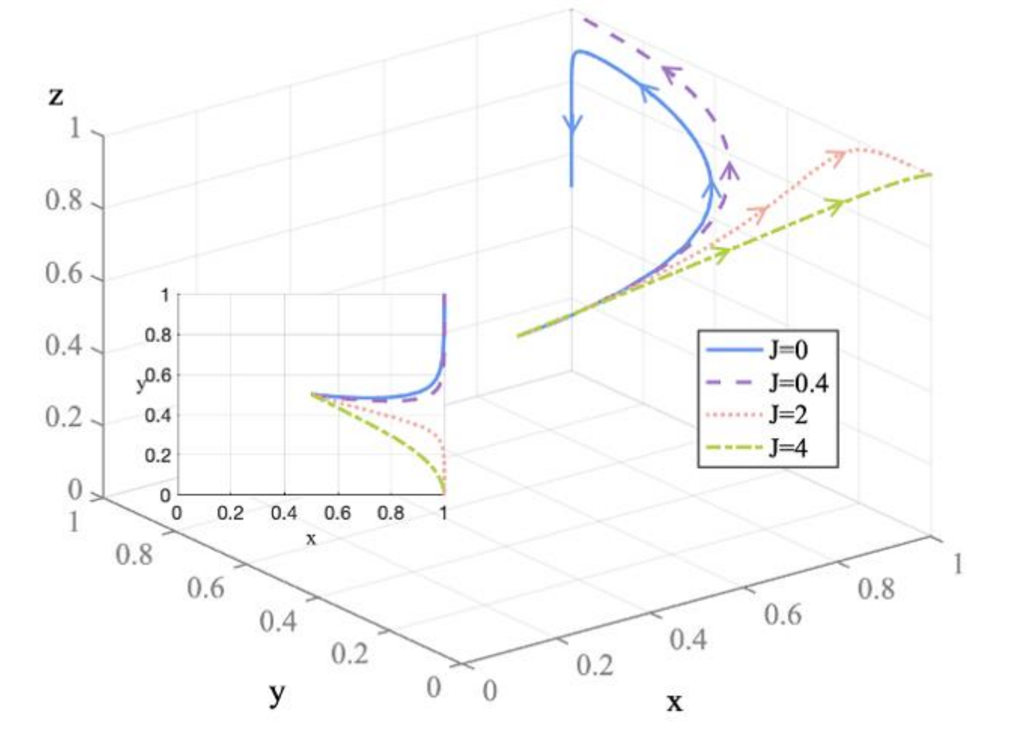


Figure 5.9 Evolutionary paths of the three parties given different rewards to developers.

Observation 5.4. Excessive or insufficient rewards for developers cannot guarantee an ideal outcome. Increasing rewards to developers within a reasonable range is conducive to GB promotion.

From Figure 5.9, when no rewards ($J = 0$) are provided, the situation is undesirable, with only some developers choosing to construct GBs, and the government's GB promotion goals are not effectively achieved. On the other hand, too few rewards ($J = 2, 4$) lead to developers quickly evolving to construct GBs, but local governments fail to fulfil their responsibilities and only partially implement GBPs. As discussed in Section 5.5, $F + P_l + S_l > J + L + c_l$ and $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ must simultaneously satisfy to achieve the ideal state. Therefore, if J is too high or too low, these conditions cannot be met, and the ideal outcome cannot be achieved. When the reward is too low, it cannot adequately compensate for the additional costs of constructing GBs for developers; when the reward is too high, it increases the fiscal burden on local governments.

5.6.3.2 Impact of rewards to consumers

By changing the value of T, Figure 5.10 depicts the evolution paths of the three parties. Unlike the evolution paths under different rewards to developers, the choices of these three parties will eventually evolve into the same stable strategy, which is E8(1,1,1).

Observation 5.5. Higher rewards to consumers are more conducive to GB promotion.

As shown in Figure 5.10, the evolution speed of developers to constructing GBs increases significantly as T increases, indicating that rewards to consumers effectively promote developers' GB development behaviour. With no rewards ($T = 0$), developers' behaviour cannot converge to constructing GBs. As discussed in Section 5.5, developers' behaviour stabilises at constructing GBs only when $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ is satisfied. Therefore, insufficient rewards for consumers, coupled with insufficient rewards for developers, cannot ensure the development of GB by developers. Therefore, rewards for consumers indirectly affect developers' behaviour.

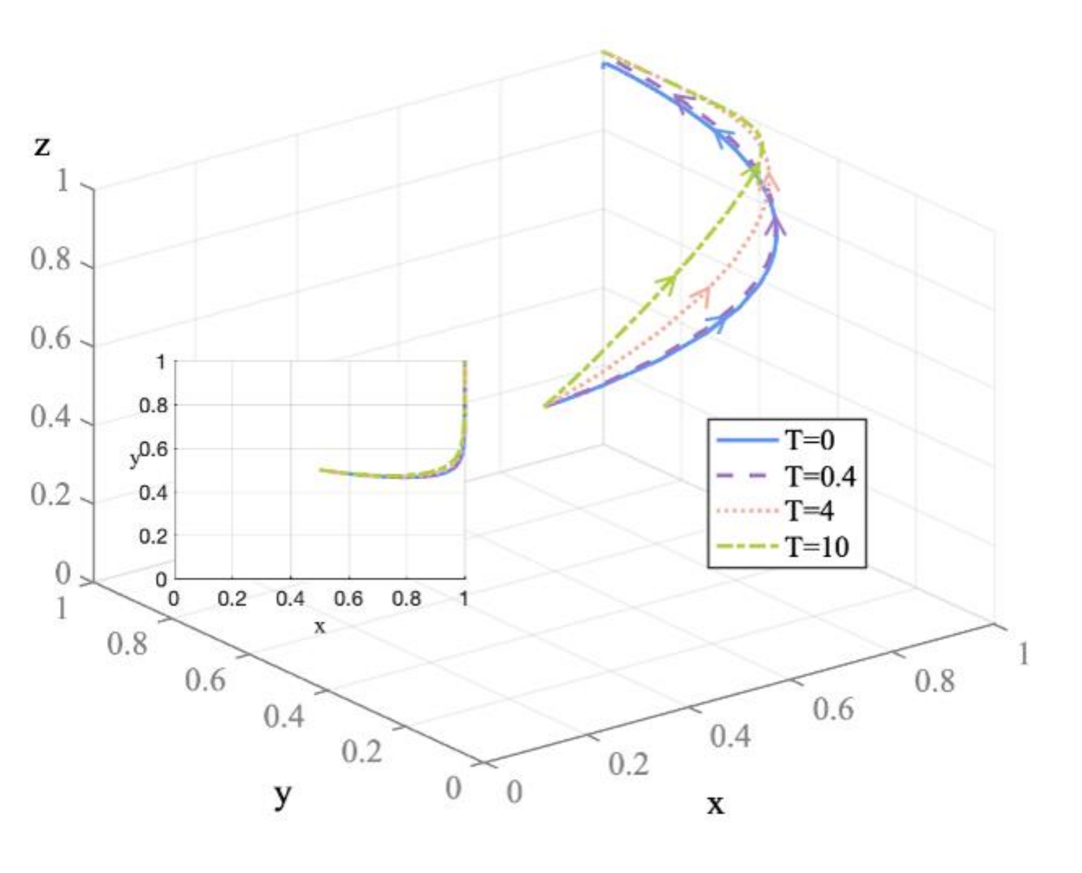


Figure 5.10 Evolutionary paths of the three parties given different rewards to consumers.

5.6.3.3 Comparison of the impacts of J and T

Given that relatively higher rewards to developers and consumers increase the evolution speed of developers to construct GBs, this subsection further compares the impacts of these two rewards. When changing J, T remains to be 0. Similarly, when changing T, J remains to be 0. Figure 5.11 shows the comparison results.

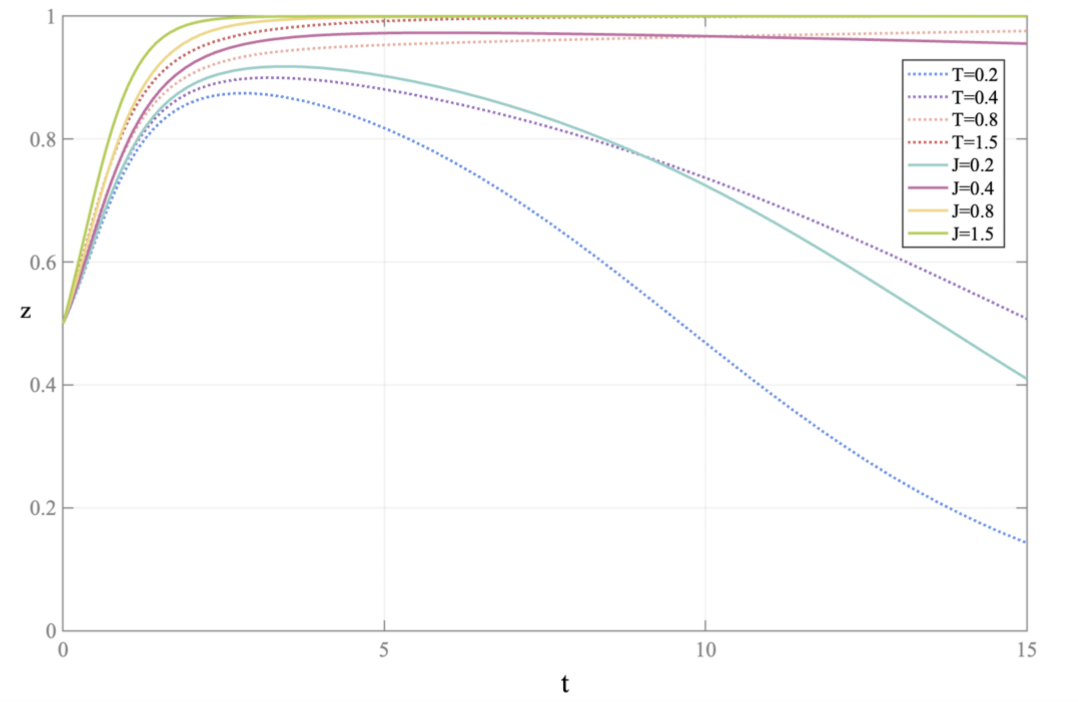


Figure 5.11 Evolutionary paths of developers given different T and J.

Observation 5.6. Directly incentivising developers is more efficient in promoting GBs compared with incentivising consumers.

Figure 5.11 shows that as rewards increase, developers' behaviour eventually converges to constructing GBs. Lower rewards leave developers lacking the motivation to choose GBs, which is consistent with the findings above. Notably, incentivising developers makes them reach the equilibrium point faster than incentivising consumers (e.g., $T = J = 1.5$). Therefore, directly incentivising developers enables faster full-scale development of GB. Q. Feng et al. (2020) found similar results, revealing that merely subsidising consumers can not effectively increase developers' enthusiasm for constructing GBs.

5.6.3.4 Impact of rewards to local governments

By changing the value of F, the evolutionary paths of the three parties are shown in Figure 5.12.

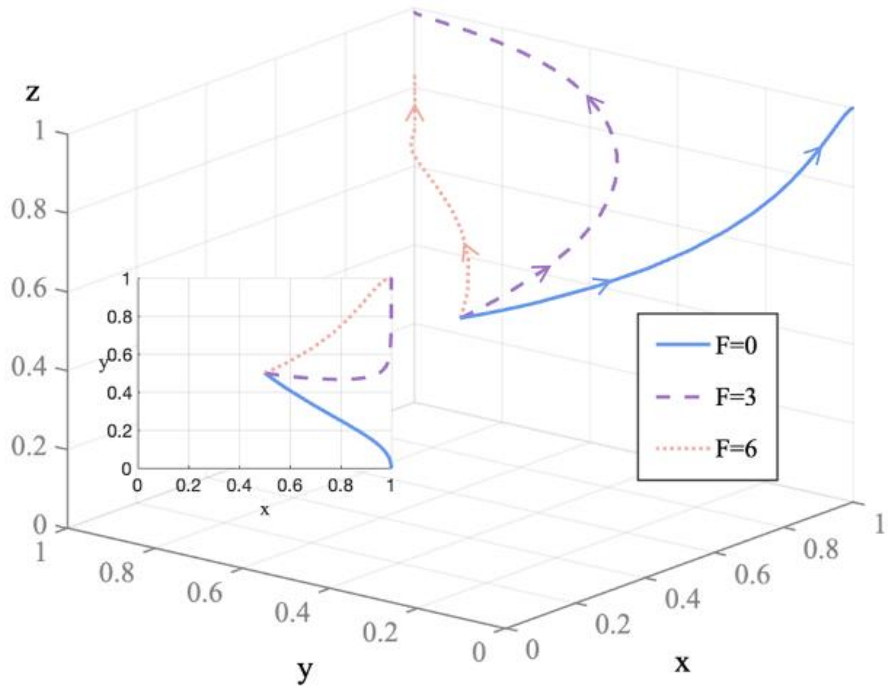


Figure 5.12 Evolutionary paths of the three parties given different rewards to local governments.

Observation 5.7. Rewards to local governments need to be controlled within a reasonable range; otherwise, it hinders GB promotion.

Observing Figure 5.12 reveals that without rewards to local governments ($F = 0$), local governments converge towards "partial implementation". This scenario is detrimental to GB promotion. Conversely, excessive rewards ($F = 6$) lead to accelerated convergence towards "full implementation" by local governments but result in developers engaging in behaviours that hinder GB promotion, with only a portion of developers choosing to construct GBs. On the other hand, when the rewards are moderate ($F = 3$), the behaviours of all three parties eventually converge to the ideal situation, where the central government maintains strict oversight, local governments fully implement GBPs and developers construct GBs.

5.6.4 Impact of government penalties

Based on the parameter values set above, this subsection analyses the impact of government punishments by respectively changing the value of P_c, P_l and P_d.

5.6.4.1 Impact of penalty for collusion

The evolutionary paths of the three parties under different penalties for collusion are shown in Figure 5.13. The three parties ultimately evolve to E8(1,1,1) with varying speeds of evolution under different P_c.

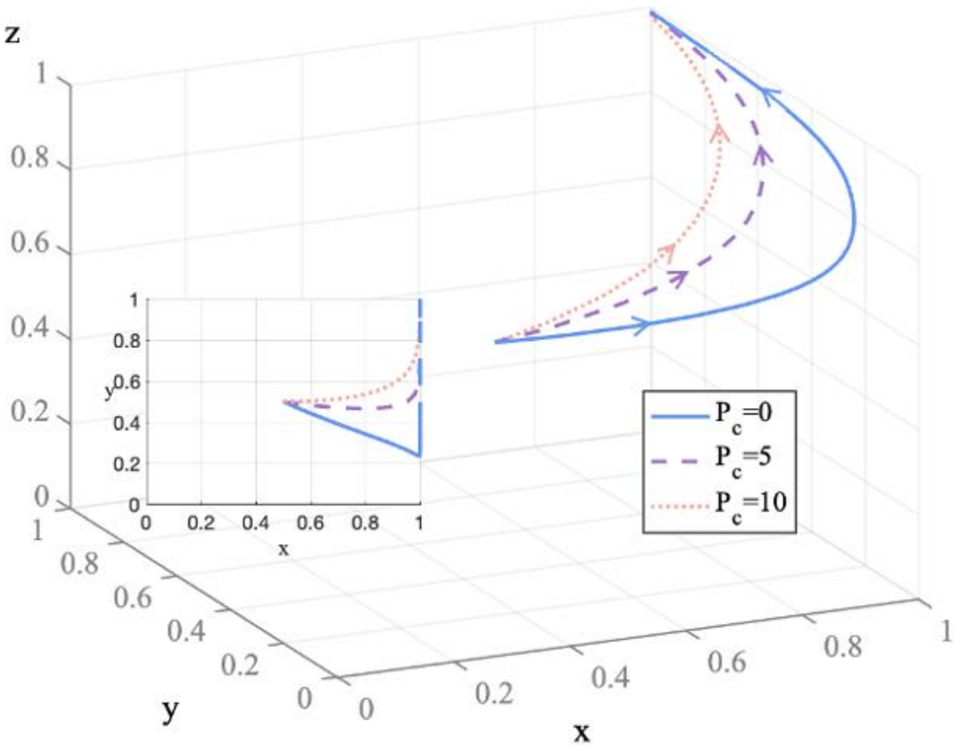


Figure 5.13 Evolutionary paths of the three parties given different penalties for collusion.

Observation 5.8. Increasing penalties for collusion are conductive in GB promotion.

Figure 5.13 shows that, with the increase of P_c, the evolution speed of the three parties accelerates significantly, stabilising at the ideal equilibrium point shortly. With heavier penalties, developers and local governments will bear greater penalty costs if they choose to deviate from the central government's strategic plan. Thus, severe penalties effectively discourage collusion.

5.6.4.2 Impact of penalty to local governments

As shown in Figure 5.14, as the central government imposes higher penalties on local governments to regulate their behaviours, the GB promotion system evolves from E6(1,0,1) to E8(1,1,1).

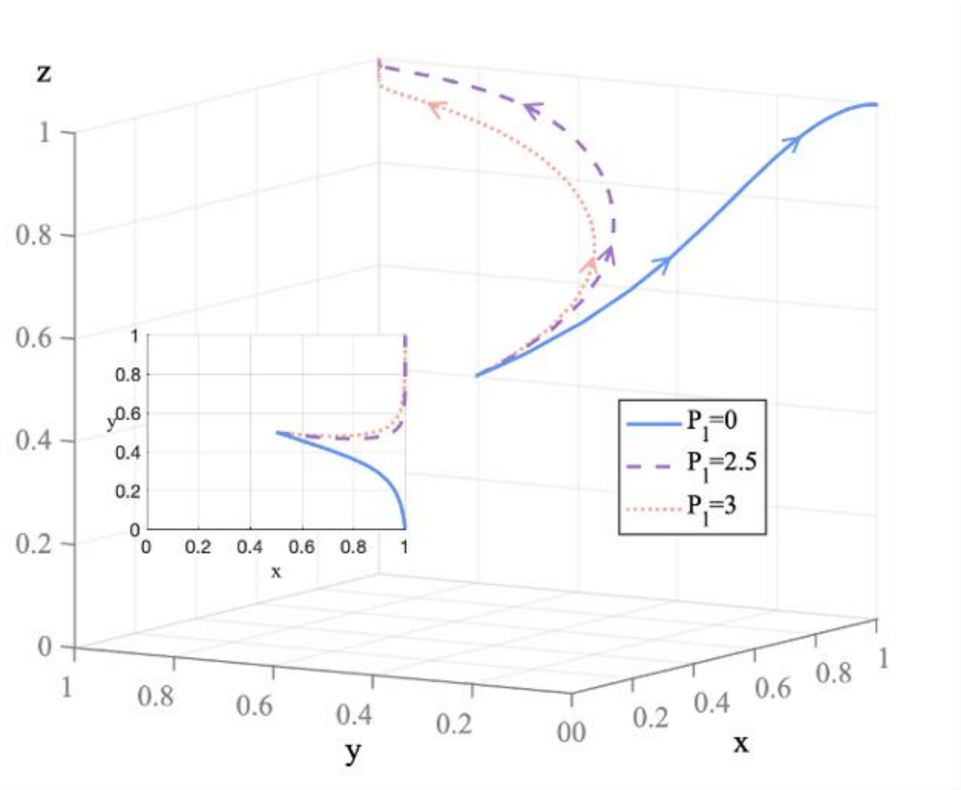


Figure 5.14 Evolutionary paths of the three parties given different penalties to local governments.

Observation 5.9. Penalties to local governments need to be controlled within a reasonable range; otherwise, it hinders GB promotion.

Figure 5.14 shows that the evolutionary path of developers speeds up significantly as the penalties to local governments rise, resulting in achieving GB promotion at a faster speed. Nevertheless, when P_l is relatively large ($P_l = 3$), the speed developers converge towards constructing GBs significantly slows down. Thus, both excessively low or high penalties are detrimental to the development of GB in China.

5.6.4.3 Impact of penalty to developers

By changing the value of P_d, Figure 5.15 presents the evolutionary paths of the three parties. The GB promotion system evolves from a non-stable state (0,y,1) to the ideal stable state E8(1,1,1) as P_d increases.

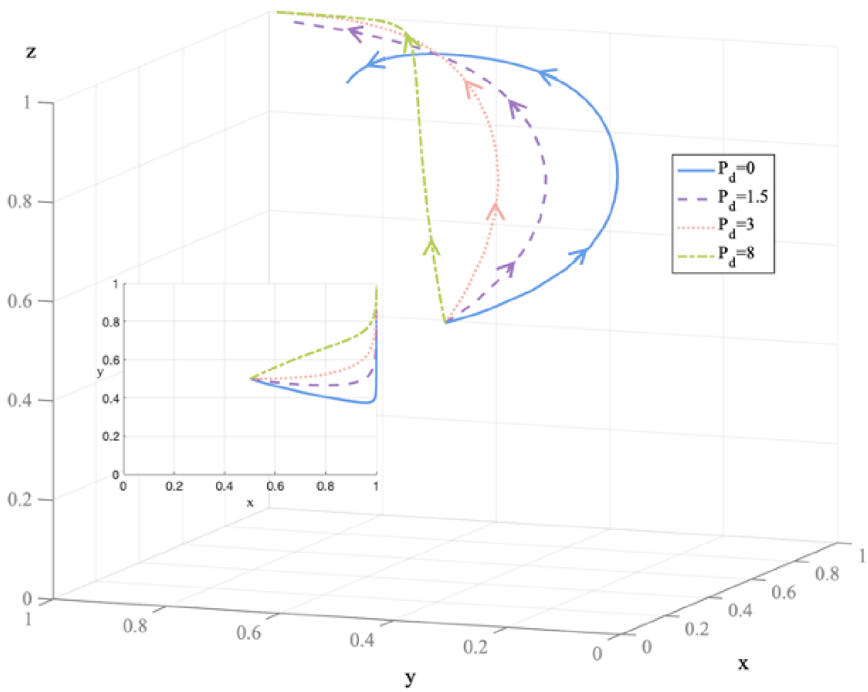


Figure 5.15 Evolutionary paths of the three parties given different penalties to developers.

Observation 5.10. Higher penalties to developers are more conducive to GB promotion.

When P_d is relatively large, the rate at which developers converge to constructing GB increases significantly as P_d increases, indicating punishing developers effectively promotes developers'

GB development behaviour. Conversely, removing the penalty does not guarantee that developers will choose to construct GBs. Specifically, when $P_d = 0$, only some developers choose to construct GBs, and local governments do not evolve to the ideal state of "full implementation". This is because when penalties for developers are low, local governments can not receive sufficient fine revenues and lack the motivation to implement GBPs fully. Meanwhile, the lower penalties do not significantly deter developers from constructing TBs, even if they do not comply with the local governments' GB requirements, as the penalties are not severe enough.

5.6.4.4 Comparison of the impacts of P_c and P_d

Given those relatively higher penalties for collusion and developers increase the evolution speed of developers to construct GBs, this study further compares the impacts of these two penalties. When P_c/P_d changes, the other constant is kept, and a value of 0 is assigned. The comparison result is shown in Figure 5.16.

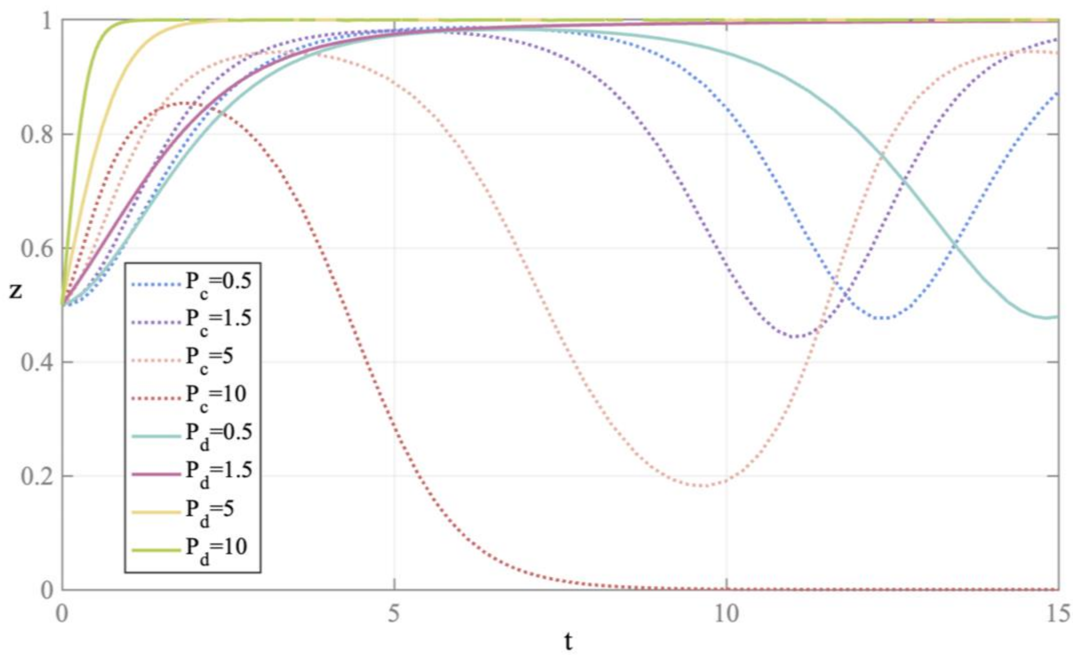


Figure 5.16 Evolutionary paths of developers given different P_c and P_d.

Observation 5.11. Higher penalties for developers are more efficient in promoting GB than penalising collusion.

Figure 5.16 shows that in the absence of penalty for developers, increasing penalties for collusion leads developers to converge towards constructing TBs instead of GBs. Conversely, when there is no penalty for collusion, increasing penalties to developers drives the full-scale development of GB faster. This implies that without penalising developers, solely increasing the penalty for collusion cannot motivate developers to comply with GB requirements. However, Observation 5.8 suggests that increasing penalties for collusion does accelerate the evolution of developers towards building GBs. This apparent contradiction can be explained by the different simulation settings. In Figure 5.16, the simulation sets $P_d = 0$, while in Figure 5.13, $P_d = 1.5$. This discrepancy highlights the importance of penalising developers. Even if the penalties for collusion is increased, without appropriate penalty for developers, they cannot exhibit the desired behaviour of constructing GBs. Therefore, directly penalising developers and increasing penalties are important.

5.6.5 Impact of consumers' green preference payment coefficient

Based on the parameter values set above, this subsection analyses the impact of heterogeneous consumers' green preference payment coefficient by changing the value of θ. Figure 5.17 shows the GB promotion system evolving from E5(1,1,0) to E8(1,1,1) as θ increases.

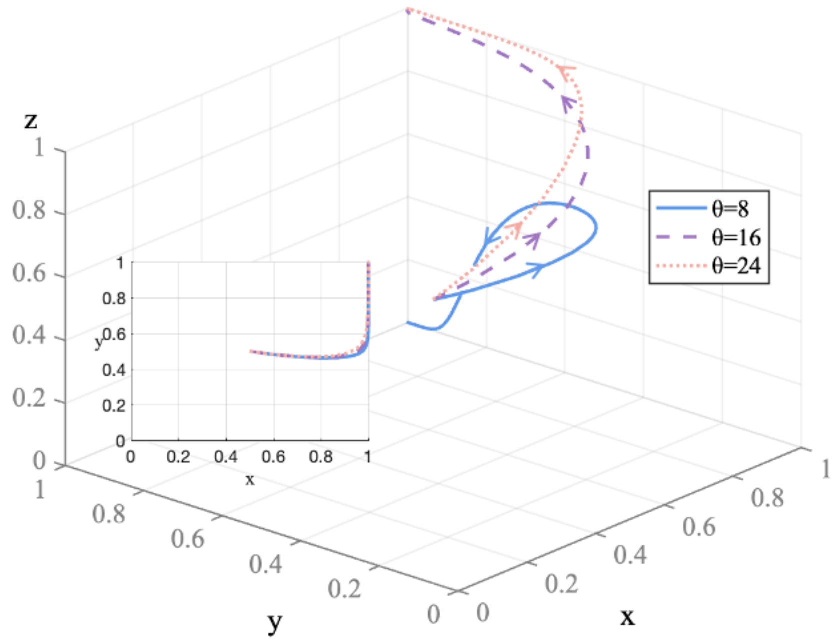


Figure 5.17 Evolutionary paths of the three parties given different green preference payment coefficient.

Observation 5.12. Higher green preference payment coefficient benefits GB promotion.

As indicated in Figure 5.17, when consumers' green preference payment coefficient is low (e.g., $\theta = 8$), developers tend to construct TBs. Such a situation is undesirable because the GB promotion has not been fully achieved. As discussed in Section 5.5, $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ must satisfy to achieve the ideal state. Therefore, if θ is lower than a certain level, leading to $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) > 3(J + P_d) + 2T + \theta(e_g - e_t)$, the ideal outcome cannot be achieved. As θ increases beyond a certain level, the GB promotion system reaches the ideal state, and developers' evolution speed to build GBs is significantly enhanced. Improving heterogeneous consumers' green preference payment coefficient is essential in GB promotion. Additionally, when consumers exhibit a low willingness to pay for each increase in building greenness, local governments can facilitate GB promotion through incentive mechanisms. This involves appropriately increasing J, P_d and T to satisfy the condition $2(c_g - c_t) + 3\mu({e_g}^2 - {e_t}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$.

5.6.6 Impact of GB greenness

Based on the parameter values set above, this subsection analyses the impact of GB greenness by changing the value of e_g. Figure 5.18 shows the GB promotion system evolves from E5(1,1,0) to E8(1,1,1), and eventually back to E5(1,1,0) as e_g increases.

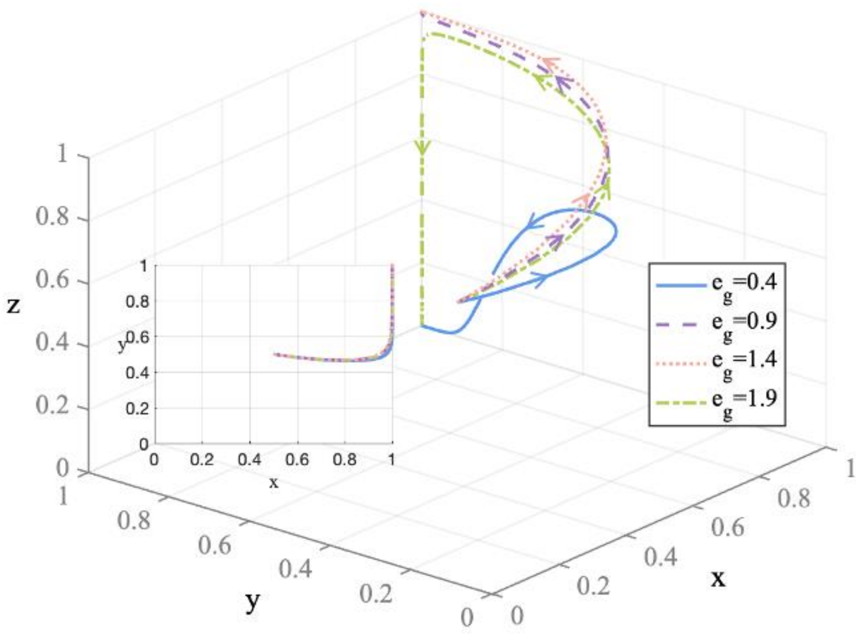


Figure 5.18 Evolutionary paths of the three parties given different GB greenness.

Observation 5.13. Moderate GB greenness contributes to GB promotion; otherwise, intensified rewards and penalties are required to attain higher GB greenness.

As shown in Figure 5.18, when there is no difference in greenness between GBs and TBs, developers will opt to construct TBs. This indicates that GBs lack a competitive advantage in the market and incur higher construction costs. When GB greenness is within a moderate range, higher greenness can prompt developers to choose green development more rapidly. However, when GB greenness is excessively high (e.g., $e_g = 1.9$), developers may initially evolve towards constructing GBs but will ultimately revert to TBs. As analysed in Section 5.5, the condition $2(c_g - c_t) + 3\mu(e_g{}^2 - e_t{}^2) < 3(J + P_d) + 2T + \theta(e_g - e_t)$ must be met to achieve the ideal state. When GB greenness is too high, $2(c_g - c_t) + 3\mu(e_g{}^2 - e_t{}^2)$ will exceed $3(J + P_d) + 2T + \theta(e_g - e_t)$. This implies that the research and development costs of GBs are too high, and the market's preference for GBs is insufficient to offset these costs, with government incentives also failing to bridge this gap. This explains the scarcity of high-level GBs in the market (C. He et al., 2021). Therefore, if the government aims to promote GBs with higher greenness, such as high-quality GBs, it can do so by increasing rewards and penalties to satisfy the inequality condition.

5.6.7 Comparison with previous research

(1) Two-Level government

Previous research has often overlooked the conflict of interest between central and local governments, assuming their actions to be consistent. The key contribution of this chapter is to elucidate the behavioural characteristics of different levels of government and developers from the perspective of MLG, thereby revealing the dynamic interaction in promoting GBs. Although Qiao et al. (2022) acknowledged the strategic inconsistency between central and local governments, their research exclusively focused on the local government, neglecting the impact of central regulation on the GB market. Unlike previous studies, this chapter unveils the distinct behavioural mechanisms of the central and local governments: on the one hand, the central government might adopt actions favourable to the promotion of GBs, such as strict supervision; on the other hand, local governments may make behavioural choices based on their own interests, not always aligning with the central government's promotion objectives, such as partial policy implementation. Thus, this study highlights the behavioural differences between central and local governments and emphasises the importance of the central government's leadership in strict supervision (see Observation 5.1).

Additionally, the behaviour of different levels of government influences other stakeholders differently. Propositions 5.2 and 5.3 indicate that the promotional behaviours of the central government (strict supervision) can induce local governments and developers to engage in behaviours favourable to promotion (full implementation and construction of GBs). However, the promotional behaviours of local governments cannot directly lead developers to adopt corresponding promotional behaviours (see Corollary 5.3.1). Only when local governments impose more severe penalties will more developers be inclined to develop GBs, as more local governments fully implement GBPs. In contrast, Guo et al. (2022) argued that local promotional behaviours can always stimulate developers' promotional behaviours, as they did not consider the role of the central government. The findings of this chapter theoretically support C. He et al.'s (2021) empirical observation that local policies do not always promote the diffusion of GBs. Additionally, they offer a theoretical explanation for the regional inequalities and insufficient central regulation discussed in Chapter 4.

(2) Policy incentive mechanisms

Previous studies, having considered only a single level of government, analysed the incentive mechanisms of governments towards developers and consumers but lacked discussion on the rewards from the central to local governments and the penalties for local governments and government-enterprise collusion. This chapter finds that, to promote GBs, the central government needs to control rewards and penalties to local governments within a moderate range (see Observations 5.7 and 5.9), while intensifying penalties for local government-developer collusion (see Observation 5.8). Blindly increasing rewards and penalties is undesirable as it may have adverse effects on the promotion of GBs (Y. Liu et al., 2022). Additionally, this chapter discusses the incentive mechanisms for developers and consumers.

In terms of rewards, rewarding both developers and consumers can promote the adoption of GBs (L. Zhang et al., 2018a; Zou et al., 2017). The findings of this chapter further deepen this understanding. As discussed in Corollary 5.3.3 and Observation 5.5, increasing rewards to consumers by local governments can lead more developers to construct GBs and accelerate their evolution speed. However, rewards to developers should be kept within a moderate range; otherwise, local governments may abandon full policy implementation (see Observation 5.4). With the same reward intensity, direct rewards to developers are more effective (see Observation 5.6). This finding is consistent with Feng et al. (2020). Regarding penalties, Observation 5.11 shows that, under the same penalty intensity, directly penalising developers is more effective than penalising collusion in expediting their transition towards GB construction. Similarly, Qiao et al. (2022) found that the higher the penalties from the government, the faster developers choose to construct GBs. This suggests that local governments' penalties can deter developers' speculative behaviour to some extent. However, this chapter further reveals that, compared with penalties for collusion, directly penalising developers is more effective. Thus, as direct suppliers of GBs, the incentive mechanisms of local governments to developers are particularly important.

5.7 Chapter Summary

Revealing the intrinsic logic of GB promotion under MLG helps advance the development of GB, facilitate the sustainable transformation of the construction industry and achieve the "dual carbon" goals. By constructing a tripartite evolutionary game model involving central and local governments as governors and real estate developers as the governed within China's MLG system, this chapter explores the dynamic interactions of stakeholders in the promotion of GBs. Firstly, the dynamic behaviours and influencing factors of the central government, local governments and developers are analysed. Secondly, the complex behavioural interaction mechanisms among stakeholders in the GB promotion system are revealed, and the stability of the system is discussed. Finally, numerical simulations are used to examine the impacts of initial willingness, costs, rewards, penalties, green preference payment coefficients and GB greenness on the evolutionary paths and speeds of the three parties, exploring the main drivers of GB promotion. The analysis leads to the following conclusions:

1. The behaviours of the actors interactively influence each other. When the central government's willingness for strict supervision increases, more local governments and developers will choose to fully implement GBPs and construct GBs. However, if more local governments opt for full implementation, the central government will reduce its willingness to enforce strict supervision, which will not necessarily lead to more developers choosing to construct GBs. Conversely, if more developers choose to construct GBs, the central and local governments may not necessarily relax supervision and partially implement policies.
2. In the ideal promotion path, where the central government strictly supervises, local governments fully implement and developers construct GBs, the central government will always evolve to strict supervision first, while the order in which local governments and developers evolve to a stable state depends on their initial willingness. In general, with a lack of promotional willingness, central and local governments will converge to "strict supervision" and "full implementation" more quickly, whereas developers will converge to constructing "GBs" more slowly.
3. The main factors influencing the collective promotion of GBs include costs, rewards, penalties, consumers' green preference payment coefficients and building greenness. High costs of GB-related activities and GB greenness, coupled with low consumer willingness to pay for GBs, hinder the formation of the ideal promotion path. Regarding penalties, increasing penalties for collusion and developers can expedite the system's convergence to the ideal state. However, excessive penalties from central to local

governments can prolong the time required to reach the ideal state. Regarding rewards, only when rewards from the central to local governments and from local governments to developers are within a reasonable range can the ideal promotion path be achieved.

4. The effectiveness of different incentive measures varies. Direct rewards to developers are more effective than rewards to consumers in accelerating the promotion of GBs. Similarly, direct penalties to developers are more effective than penalties for collusion in accelerating their decision to construct GBs.

CHAPTER 6 Policy Incentive Mechanisms Design for GB Promotion[3]

6.1 Introduction

Chapter 5 demonstrates that appropriate incentive measures for local governments and developers are essential for effectively promoting GBs in an environment characterised by information asymmetry. However, determining the precise value of "appropriate" incentives and how to achieve policy objectives while aligning with the interests of agents remains unresolved. The promotion of GBs is accompanied by information asymmetry between different levels, which can foster opportunistic behaviour. Despite central supervision and incentives, local governments may enforce GBPs but opt to promote lower-quality GBs to quickly achieve political goals and save costs, rather than prioritising higher-quality GBs, resulting in moral hazard (H. Jiang & Payne, 2019). Moreover, there may be collusion, such as exaggerating the environmental benefits of GB projects to gain policy favour (moral hazard). For developers, if government incentives fall short of their expectations, those with sufficient capacity may conceal their true capabilities (adverse selection) and opt to construct lower-level GBs, refusing to invest additional resources to improve building greenness (moral hazard). Over time, this can lead to the proliferation of "greenwashing" practices, undermining the sustainable development of GBs. Current research (P. Jiang et al., 2016) indicates that insufficient incentives for high-level GBs have resulted in the suboptimal promotion of GBs. However, simply increasing incentives to foster high-quality GB development is neither practical nor sustainable. Therefore, there is a need to devise effective and reasonable incentive

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[3] This chapter is relevant to the publication:

Hu, Q., Xiong, F., Shen, G. Q., Liu, R., Xue, J., Wu, H., & Zhou, X. (2024). Incentive Mechanism Design for Promoting High-Quality Green Buildings in China's Multi-Level Governance System. *Building and Environment*, 112358.

mechanisms to address the adverse selection and moral hazard issues stemming from information asymmetry, ensuring incentive compatibility without imposing excessive costs.

Based on the ideal promotion path outlined in Chapter 5, where the central government, local governments and developers collaboratively promote GBs, this chapter considers the principal-agent relationships among these three parties. Building on the GBP framework characteristics discussed in Chapter 4, a dual principal-agent model is developed to design optimal policy incentive mechanisms under information asymmetry for GB promotion. This model aims to foster the active participation of local governments and developers, improving the quality of GBs and facilitating information discernment, thereby promoting the widespread adoption of high-quality GBs.

First, a dual principal-agent model is developed to incorporate China's MLG context and the practical implementation of the GB market. This model incorporates key stakeholders, including the central government, local government and developer. Incentive mechanisms are then designed for various scenarios. Comparative analysis of these mechanisms is conducted, followed by a numerical investigation to explore the impact of different factors on the incentive mechanisms. The theoretical model provides feasible recommendations for the central government's top-level design and local government policy formulation.

6.2 Problem Description and Assumptions

6.2.1 Problem description

Combining the analysis of the behaviour of key players in the MLG system for promoting GBs in Chapter 5, it can be observed that there is a dual principal-agent relationship among the central government, local governments and developers. Specifically, in the process of promoting GBs, the central government is responsible for setting the policy direction and establishing performance evaluation mechanisms for local governments. Local governments, entrusted by the central government, are responsible for implementing GBPs. They develop local GBs according to the performance evaluation mechanism and their objective of utility maximisation. They exercise management authority over local developers and choose appropriate measures (such as supervision and incentives) for implementation. Essentially, a top-down principal-agent relationship is formed between the central and local governments, with the central government in the position of the principal and the local government in the position of the agent. In the principal-agent relationship between the central and local governments, the local government, as the executing body of local affairs, is closer to the information source and naturally has an information advantage. Local government is responsible for providing the central government with the necessary information to meet its requirements. However, this also creates information asymmetry between the central government (principal) and the local government (agent), which means that a rational agent can use this information advantage to pursue its own interests, potentially engaging in passive or false execution of the principal's tasks, even leading to the failure of the principal's goals, resulting in moral hazard. For instance, in the central government's "*14th Five-Year Plan for Building Energy Efficiency and Green Building Development*", conditional local governments are encouraged to promote the construction of high-star-rated GBs. However, in practice, promoting high-star-rated GBs requires higher implementation costs. Even conditional local governments might opt to promote lower-star-rated GBs to meet the central government's assessment targets for economic reasons.

On the other hand, developers, as the suppliers of building products, directly determine the building's greenness and play the role of agents in the task of promoting GBs. Improving the greenness of building products inevitably involves substantial cost inputs, such as using more environmentally friendly materials. In a market economy, developers are driven by the pursuit of profit maximisation. Rationally, if the inputs from developers do not bring economic benefits or fail to cover the investment costs, they may not voluntarily improve the greenness of buildings. Instead, they will make rational choices within the constraints of external resource environments to meet the public demand for GBs and comply with government environmental regulations. In China's GBP system, local governments are responsible for supervising and guiding the development work of local developers. From the perspective of information economics, there is a principal-agent relationship between local governments and developers. Local governments act as the principals, while developers are the agents. Under market economic conditions, developers, as agents, have significant autonomy and possess more and more accurate information about their microeconomic activities. Principals cannot monitor all the behaviours of developers. Developers may conceal their cost information and development status, making it difficult for local governments, as principals, to verify. Therefore, when local governments cannot determine the real behaviour of agents and implement corresponding reward and penalty measures, developers may choose to reduce efforts to save costs or exaggerate real costs to obtain more policy benefits, thus increasing their profits and maximising their own utility.

The central government, representing the national public interest, is committed to the coordinated development of economy, society and environment, as well as the maximisation of overall benefits. However, the central government mainly entrusts local governments to supervise and implement the promotion of GBs by developers; thus, it cannot obtain timely, comprehensive and accurate information about the actual situation and results. Under these circumstances, opportunistic behaviour through collusion between local governments and developers is possible. For example, local governments and developers may collude to exaggerate the environmental benefits of GB projects. The evaluation of environmental benefits itself involves some subjectivity and interpretability, which may lead to some errors or discrepancies, providing space for local governments to exaggerate and falsely report, inevitably triggering moral hazard problems. Moreover, existing research (Lo, 2014) also indicates the possibility of data manipulation. Such collusion undermines the original intention and principles of GBPs, damages the sustainable development of the GB industry, weakens the effectiveness of government policies and hinders the realisation of public interests.

Generally, principals find it relatively easy to observe natural states but relatively difficult to obtain real information and supervise the behaviour of agents. However, the final result is common knowledge, which means that the principal's acquisition of real information about agents and the supervision of their behaviour is equivalent to observing natural states. Therefore, under information asymmetry, principals can only infer agents' real information and actions by observing their natural states and vice versa. Ensuring that agents truthfully disclose their real information and take actions that align with the principal's interests, e.g., solving the problems of adverse selection and moral hazard caused by information asymmetry, becomes a crucial issue. In information economics, incentive mechanisms are regarded as key means to improve agent efficiency. Hence, designing incentive mechanisms becomes a method to address adverse selection and moral hazard caused by information asymmetry. The core principle of such mechanisms is for the principal to reward agents for providing more information through a distribution system to narrow the gap of information asymmetry. Essentially, incentive mechanisms are effective supplements to incomplete contracts, aiming to align the decision-making goals of agents with the interest goals of principals. Based on an in-depth analysis of the principal-agent relationships and the problems arising from them in GB promotion, corresponding incentive mechanisms can be designed to prompt agents to better fulfil their duties and achieve the goals of principals.

In summary, as shown in Figure 6.1, this chapter considers a dual principal-agent relationship, with the central government acting as the "pure principal", the developer as the "pure agent", and the local government as an "intermediary" serving as principal and agent. The central government entrusts the local government with implementing GBPs, utilising incentive mechanisms such as transfer payments. This represents the first layer of the principal-agent relationship. The developer, as the direct executor of GB projects, directly impacts the quality of GBs. Consequently, the local government depends on the developer to enhance GB quality and employs subsidies as incentives, forming the second layer of the principal-agent relationship. In situations of information asymmetry, agents have the incentive to reduce efforts in improving GB quality, such as reducing investments, or to engage in collusion to overstate and misreport environmental benefits. These behaviours pose moral hazards. Additionally, imperfect market mechanisms in China grant developers autonomy and the ability to conceal cost information. The developer possesses private cost information that is challenging for the government to observe or obtain. Consequently, a self-interested developer may manipulate its costs to obtain government subsidies, resulting in adverse selection issues. Given these circumstances, principals in the aforementioned principal-agent relationships aim to establish incentives and constraints through contract design within an environment characterised by information asymmetry. This approach aims to align the interests of principals and agents, ultimately facilitating the achievement of their respective objectives.

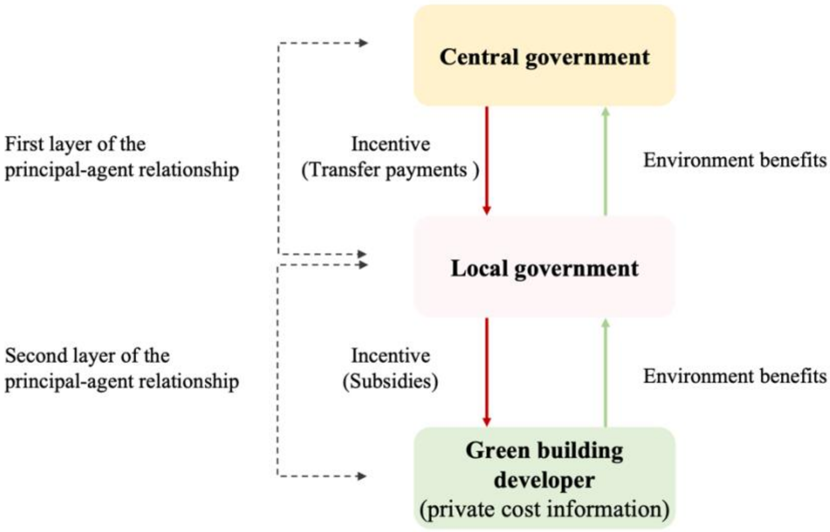


Figure 6.1 Dual principal-agent relationship in GB promotion.

Decision sequences within the dual principal-agent relationship are as follows: (1) The "pure principal" central government determines the incentive mechanism provided to the "intermediary" local government. (2) The local government decides whether to accept the mechanism and, if accepted, designs incentive mechanisms for the "pure agent" developer based on the central government's incentive, simultaneously determining its own green effort strategy (Note: In collusion scenarios, the determination of overstated environmental benefits is also considered). (3) The developer decides whether to accept the mechanism and, if accepted, determines its green effort strategy based on the local government's incentive mechanism. (4) The local government observes the developer's GB greenness and fulfils contractual payments. (5) The central government observes regional environmental benefits and fulfils contractual payments.

6.2.2 Notations

For ease of description, subscripts "c", "l", "d" and "e" respectively represent "central government", "local government", "developer" and "environment". Considering that the developer possesses private cost information, the subscript "L" denotes the low-cost type, while "H" represents the high-cost type. The superscripts "*" and "**" signify optimal decisions under non-collusion and collusion scenarios, respectively. The variables, parameters and their corresponding definitions involved in this study are presented in Table 6.1. The selection of parameters considers the results from Chapter 3 and previous studies.

Table 6.1 Description of variables and parameters.

Notations	Descriptions
Decision Variables	
e_i	Green effort level chosen by the developer, $i \in \{H, L\}$
b_i	Profit distribution ratio provided by the local government to the developer, measuring incentive intensity, $i \in \{H, L\}$
a_i	Fixed payment provided by the local government to the developer, $i \in \{H, L\}$
m	Environment benefits misreported by the local government
n	Green effort level of the local government
α	Fixed payment provided by the central government to local government
β	Profit distribution ratio provided by the central government to local government, measuring incentive intensity
Parameters	

h_i	Cost coefficient of green efforts for the developer, $i \in \{H, L\}$, where h_H represents the high-cost developer and h_L represents the low-cost developer, $h_H > h_L$
μ	Cost coefficient of green efforts for the local government
θ	Low-cost developer market share (public information), $\theta \in [0,1]$
γ	Coefficient of GB greenness for developer's green efforts (Cai D. et al., 2023)
g	GB greenness, measuring the quality of GB (Cai D. et al., 2023; L. He & Chen, 2021)
λ	Central government's penalty coefficient for collusion behaviour (X. Yang et al., 2021)
c_{di}	Incremental cost of GB (W. He et al., 2022)
c_l	Local government's cost of green efforts (X. Yang et al., 2021)
p_i	Selling price of GB, $p_i \geq c_{di} > 0$
ρ_2	Local government's risk aversion coefficient, $\rho_2 > 0$(X. Yang et al., 2021)
ρ_1	Developer's risk aversion coefficient, $\rho_1 > 0$(X. Yang et al., 2021)
f	Central government's penalty for collusion behaviour (X. Yang et al., 2021)
U_0	Reserved utility
π	Profit

U	Utility
W	Social welfare

6.2.3 Assumptions

Preserving the essence of the problem, the model incorporates certain simplifications of intricate conditions, leading to the following assumptions:

Assumption 6.1. Participant risk preference assumption. The central government is risk-neutral, given its ample resources and authority. By contrast, the local government and developer, constrained by limited resources, adopt risk-averse preferences in decision-making, reflected by their utility function $U(\pi) = -e^{-\rho\pi}$ (X. Yang et al., 2021).

Assumption 6.2. Developer heterogeneity assumption. The market comprises high- and low-cost developers, distinguished by varying unit costs for green efforts denoted by the private information parameter h_i. Specifically, the high-cost developer bears a higher unit cost for green efforts.

Assumption 6.3. Developer strategy and cost-benefit assumption. The developer enhances GB greenness through green efforts e_i (e.g., advanced technologies, eco-friendly materials), incurring incremental costs (Y. Liu et al., 2014), modelled as $c_d(e_i) = \frac{h_i(e_i)^2}{2}$ (W. He et al., 2022). GB greenness, positively correlated with green efforts (Cai D. et al., 2023), is influenced by external factors ε_1, such as unforeseeable events. Thus, $g(e_i) = \gamma e_i + \varepsilon_1$. The government, unable to directly observe the developer's green effort level, evaluates GB greenness through a GB evaluation system (Hui & Yu, 2020; Juan et al., 2017). Greenness is considered public information, reflecting the quality of GB.

Assumption 6.4. Local government strategy and cost-benefit assumption. The local government incentivises the developer to enhance greenness in GB and contribute to environmental benefits through its own green efforts n (e.g., increased regulation, promotional campaigns, enhanced technological research and training). These efforts, incurring additional costs, are modelled as $c_l(n) = \frac{\mu n^2}{2}$ (X. Yang et al., 2021). The local government's green efforts are assumed positively correlated with environmental benefits (X. Yang et al., 2021), satisfying $\pi_l(n) = n + \varepsilon_2$, where ε_2 accounts for external random factors, indicating potential interference from unpredictable events such as natural disasters. The central government, unable to directly observe local government green efforts, quantifies environmental benefits using methods proposed by C. Zhao et al. (2022).

Assumption 6.5. Environmental benefits assumption. Environmental benefits in each region result from the collective efforts of the local government and the developer, measured in monetary terms : $\pi_e = \pi_l(n) + g(e_i)$ (X. Yang et al., 2021; C. Zhao et al., 2022).

Assumption 6.6. Stochastic variables assumption. ε_1 and ε_2 are independent normal random variables: $\varepsilon_1 \sim N(0, {\sigma_1}^2)$， $\varepsilon_2 \sim N(0, {\sigma_2}^2)$ (X. Yang et al., 2021).

Assumption 6.7. Government incentives assumption. Both central and local governments employ linear incentives, comprising fixed payments and variable profit distribution rates (X. Yang et al., 2021). The central government incentivises based on regional environmental benefits, while the local government incentivises based on GB greenness (Qiao et al., 2022). The incentive contracts for the central and local governments can be respectively expressed as $\alpha + \beta\pi_e$ and $a_i + b_i g(e_i)$. The central government can incentivise local governments through forms such as transfer payments, while the local governments can incentivise developer through subsidies.

Assumption 6.8. Reserved utility assumption. In accordance with the principal-agent model (W. Cai & Singham, 2018), reserved utilities U_0 for the local government and developer are standardised to 0 to avoid mathematical complexity; this does not alter the basic results.

6.3 Incentive Mechanisms under Non-Collusion (Model N)

This section constructs an incentive model when no collusion occurs between the local government and developer, establishing it as a benchmark and eliminating the possibility of misreporting of environmental benefits. The emphasis lies in designing optimal incentive contracts to promote truthful disclosure of information and maximise green efforts, considering the inherent asymmetry of information in the principal-agent relationships involving the central government, local government and developer. The incentive model is formulated as follows:

$$\max_{\alpha,\beta} E[\pi_c] = (1-\beta)[n + \gamma(\theta e_L + (1-\theta)e_H)] - \alpha \tag{6-1}$$

s.t.

IC:
$$e_i^* = \operatorname{argmax} E(U_{di}) \quad i \in \{H, L\} \tag{6-2}$$

$$n^*, a_i^*, b_i^* = \operatorname{argmax} E(U_l) \quad i \in \{H, L\} \tag{6-3}$$

$$U_{dH}(e_H, a_H, b_H) \geq U_{dH}(e_L, a_L, b_L) \tag{6-4}$$

$$U_{dL}(e_L, a_L, b_L) \geq U_{dL}(e_H, a_H, b_H) \tag{6-5}$$

IR:
$$U_{dH}(e_H, a_H, b_H) \geq U_0 \tag{6-6}$$

$$U_{dL}(e_L, a_L, b_L) \geq U_0 \tag{6-7}$$

$$U_l \geq U_0 \tag{6-8}$$

Where π_c, U_l and U_{di} represent the revenue of the risk-neutral central government, and the utility of the risk-averse local government and developer, respectively, in a non-collusion scenario. $\{\alpha, \beta\}$ denote the incentive contract designed by the central government, while $\{a_H, b_H\}$ and $\{a_L, b_L\}$ represent the incentive contracts designed by the local government.

Equations (6-6), (6-7) and (6-8) ensure that the developer and local government, under no collusion, accept incentive contracts if the utility exceeds their reserved utility U_0, otherwise, they reject the contract. Equations (6-2) and (6-3) ensure incentive compatibility under moral hazard, optimising green efforts for the developer and local government. Equations (6-4) and (6-5) establish incentive compatibility for the developer under adverse selection, ensuring expected utility of incentive contract $\{a_H, b_H\}$ ($\{a_L, b_L\}$) for high-cost (low-cost) developers is not lower than that of incentive contract $\{a_L, b_L\}$ ($\{a_H, b_H\}$), promoting truthful choices based on individual costs and achieving information disclosure goals. Following Myerson (1979), Equations (6-5) and (6-6) are tight. Based on the established incentive model and the decision sequence of the three parties, Sections 6.3.1 to 6.3.3 solve and analyse the optimal strategies of each stakeholder through backward induction.

6.3.1 Optimal strategy of the developer

As a pure agent, the GB developer is at the end of the decision sequence. This subsection starts from the final stage of the game and solves and analyses the developer's optimal strategy, given the local government's incentive contracts. The certainty equivalent income of the developer consists of incentives, sales revenue and costs:

$$E(\pi_{di}) = a_i + b_i g(e_i) + p_i - c_d(e_i) \qquad i \in \{H, L\} \tag{6-9}$$

Given that the developer is risk-averse, it is necessary to consider its risk cost: $\frac{\rho_1 {b_i}^2 {\sigma_1}^2}{2}$. Thus, the utility of the risk-averse developer consists of its certainty equivalent income and the incurred risk cost:

$$U_{di} = E(\pi_{di}) - \frac{\rho_1 {b_i}^2 {\sigma_1}^2}{2} \qquad i \in \{H, L\} \tag{6-10}$$

From equation (6-10), Lemma 6.1 can be derived.

Lemma 6.1. In model N, the optimal green effort of the high-cost (low-cost) developer, who truthfully chooses the high-cost (low-cost) contract is ${e_H}^* = \frac{b_H \gamma}{h_H}$ and ${e_L}^* = \frac{b_L \gamma}{h_L}$, respectively. The optimal green effort of the high-cost (low-cost) developer, who misreports its cost type and chooses the low-cost (high-cost) contract is ${e_H}'^* = \frac{b_L \gamma}{h_H}$ and ${e_L}'^* = \frac{b_H \gamma}{h_L}$, respectively.

Proof: The developer aims to maximise its own profit, so under the given contracts $\{a_H, b_H\}$/ $\{a_L, b_L\}$, it will determine the optimal green effort to maximise its expected utility, e.g., ${e_i}^* = \text{argmax}E(U_{di})$. By taking the second derivative of the developer's expected utility function, we obtain $\frac{\partial^2 U_{di}}{\partial {e_i}^2} = -h_i < 0$, thus U_{di} is a strictly concave function with respect to e_i, ensuring the existence of an optimal solution ${e_i}^*$ that maximises U_{di}. Setting the first derivative $\frac{\partial U_{di}}{\partial e_i} = 0$, we derive the optimal green effort for the developer of different cost types under different incentive contracts.

Lemma 6.1 indicates that under the non-collusion scenario, given the local government's incentive contracts $\{a_i, b_i\}$, the developer's optimal green effort solely depends on the incentive intensity b_i of the chosen contract, the private cost type h_i and the GB greenness output coefficient γ, but is independent of the local government's fixed payment a_i. Cost type, as private information of the developer, incentivises them to conceal their information. If the incentive mechanism designed by the local government is unreasonable, the developer may distort its cost type to maximise its own profit. For example, a low-cost developer might choose the contract $\{a_H, b_H\}$ to maximise its profit, misleading the local government to believe it is high-cost, ultimately leading to erroneous decisions and harming its interests.

Corollary 6.1.1. The developer's optimal green effort ${e_i}^*$ is positively correlated with the local government's incentive intensity b_i and the GB greenness output coefficient γ, and negatively correlated with its cost coefficient h_i.

Proof: $\frac{\partial {e_i}^*}{\partial b_i} = \frac{\gamma}{h_i} > 0, \frac{\partial {e_i}^*}{\partial \gamma} = \frac{b_i}{h_i} > 0, \frac{\partial {e_i}^*}{\partial h_i} = -\frac{\gamma b_i}{{h_i}^2} < 0.$

Corollary 6.1.1 shows that increasing the incentive intensity by the local government helps enhance the green effort of the developer, thereby improving the quality of GBs. This is because higher incentive intensity means that the rewards developers receive are more closely tied to their green efforts; the more effort they invest, the greater the rewards. Similarly, a higher GB greenness output coefficient means that the same level of effort results in higher GB quality, yielding more rewards. Cost, however, is a key constraint on the developer's green efforts. Higher costs lead the developer to reduce its green efforts to lower the high costs incurred by its efforts.

Corollary 6.1.2. The green effort of a low-cost developer is always at least equal to that of a high-cost developer.

Proof: Linearly adding the incentive compatibility constraints (6-4) and (6-5): $a_H + b_H \gamma e_H + p_H - \frac{h_H (e_H)^2}{2} - \frac{\rho_1 {b_H}^2 {\sigma_1}^2}{2} + a_L + b_L \gamma e_L + p_L - \frac{h_L (e_L)^2}{2} - \frac{\rho_1 {b_L}^2 {\sigma_1}^2}{2} \geq a_L + b_L \gamma e_L + p_L - \frac{h_H (e_L)^2}{2} - \frac{\rho_1 {b_L}^2 {\sigma_1}^2}{2} + a_H + b_H \gamma e_H + p_H - \frac{h_L (e_H)^2}{2} - \frac{\rho_1 {b_H}^2 {\sigma_1}^2}{2}$. Simplifying, we get: $-\frac{h_H (e_H)^2}{2} - \frac{h_L (e_L)^2}{2} \geq -\frac{h_H (e_L)^2}{2} - \frac{h_L (e_H)^2}{2}$. That is: $(e_L)^2 (h_H - h_L) \geq (e_H)^2 (h_H - h_L)$. Given $h_H > h_L$, it always holds that $e_L \geq e_H$.

Corollary 6.1.3. The low-cost developer is motivated to misreport its cost type and pretends to be a high-cost developer. Conversely, the high-cost developer has no incentive to misreport its cost type and always reports its cost type truthfully.

Proof: According to equation (6-5), we get: $U_{dL}(e_L, a_L, b_L) \geq U_{dL}(e_H, a_H, b_H) \geq U_{dL}(e_H, a_H, b_H) - (U_{dH}(e_H, a_H, b_H) - U_0) = a_H + b_H\gamma e_H + p_H - \frac{h_L(e_H)^2}{2} - \frac{\rho_1 {b_H}^2 {\sigma_1}^2}{2} - [a_H + b_H\gamma e_H + p_H - \frac{h_H(e_H)^2}{2} - \frac{\rho_1 {b_H}^2 {\sigma_1}^2}{2}] + U_0 = \frac{(h_H - h_L)(e_H)^2}{2} + U_0 > U_0$. This means that as long as the high-cost developer achieves utility not lower than its reservation utility (at which point it will construct GBs), the utility of the low-cost developer will always be higher than that of the high-cost developer. For the sake of maximising its own interests, the local government, when designing the incentive mechanism, will only allow the high-cost developer to obtain its reservation utility, satisfying the condition for participating in GB construction, e.g., $U_{dH}(e_H, a_H, b_H) = U_0$. Therefore, the low-cost developer's utility for misreporting as a high-cost developer is $U_{dL}(e_H, a_H, b_H) = \frac{(h_H - h_L)(e_H)^2}{2} + U_0 > U_0$. It can be observed that a low-cost developer disguising itself as a high-cost developer can obtain additional information rent $\frac{(h_H - h_L)(e_H)^2}{2} > 0$. Hence, the low-cost developer has the incentive to misreport as a high-cost developer to gain more benefits. For the high-cost developer, the utility obtained by falsely reporting itself as a low-cost developer is $U_{dH}(e_L, a_L, b_L) - U_{dH}(e_H, a_H, b_H) = U_{dH}(e_L, a_L, b_L) - U_{dL}(e_L, a_L, b_L) + U_{dL}(e_L, a_L, b_L) - U_{dH}(e_H, a_H, b_H) = a_L + b_L\gamma e_L + p_L - \frac{h_H(e_L)^2}{2} - \frac{\rho_1 {b_L}^2 {\sigma_1}^2}{2} - [a_L + b_L\gamma e_L + p_L - \frac{h_L(e_L)^2}{2} - \frac{\rho_1 {b_L}^2 {\sigma_1}^2}{2}] + U_{dL}(e_L, a_L, b_L) - U_{dH}(e_H, a_H, b_H) = \frac{(h_L - h_H)(e_L)^2}{2} + U_{dL}(e_L, a_L, b_L) - U_{dH}(e_H, a_H, b_H)$. Since the local government, in order to maximise its own interest, will design the contract in such a way to suppress the developer's utility to their reservation utility, we have $U_{dH}(e_L, a_L, b_L) -$

$U_{dH}(e_H, a_H, b_H) = \frac{(h_H - h_L)[(e_H)^2 - (e_L)^2]}{2} \leq 0$. This means the utility of a high-cost developer falsely reporting as a low-cost developer will not exceed the utility of truthfully reporting as a high-cost developer. Therefore, the high-cost developer will not misreport its cost type.

Corollary 6.1.4. When the price of GBs is sufficiently high, the government no longer needs to incentivise the developer.

Proof: Combining equation (6-9) with the participation constraints of the developer (6-6) and (6-7), if $p_i - c_d(e_i) \geq U_0$, then $p_i \geq c_d(e_i) + U_0$.

Corollary 6.1.4 indicates that if it is profitable to develop high-quality GBs, developers will spontaneously make green efforts to achieve high-quality GBs without the need for government incentives. However, high prices inevitably transfer high costs to consumers, which may limit consumers' willingness to purchase GBs. This phenomenon is unsustainable for the high-quality development of GBs. Therefore, when developer costs remain high, it is more feasible for the government to provide incentive mechanisms.

6.3.2 Optimal strategy of the local government

This subsection analyses the second stage of the game, which is the optimal strategy of the local government. As the "intermediary", the local government's certainty equivalent income consists of incentives from the central government, incentive expenditure to the developer and its own green effort costs:

$$E(\pi_l) = (\alpha + \beta\pi_e + b_i m) - [a_i + b_i g(e_i)] - c_l(n) \qquad i \in \{H, L\} \tag{6-11}$$

Similarly, because the local government is also risk-averse, its risk costs must be considered, which is $\frac{\rho_2[\beta^2{\sigma_2}^2 + (\beta - b_i)^2{\sigma_1}^2]}{2}$.

Accordingly, the utility of a risk-averse local government comprises its certainty equivalent income and the risk costs it faces:

$$U_l = E(\pi_l) - \frac{\rho_2[\beta^2{\sigma_2}^2 + (\beta - b_i)^2{\sigma_1}^2]}{2} \tag{6-12}$$

Given that the developer possesses private information about its costs, the local government only knows the probability θ of the developer's cost type. Thus, the utility of the local government can be expressed as:

$$U_l = \theta\{\alpha + \beta(n^* + \gamma {e_L}^*) - (a_L + b_L\gamma {e_L}^*) - \frac{\mu(n^*)^2}{2} - \frac{\rho_2[\beta^2{\sigma_2}^2+(\beta-b_L)^2{\sigma_1}^2]}{2}\} + (1-\theta)\{\alpha + \beta(n^* + \gamma {e_H}^*) - (a_H + b_H\gamma {e_H}^*) - \frac{\mu(n^*)^2}{2} - \frac{\rho_2[\beta^2{\sigma_2}^2+(\beta-b_H)^2{\sigma_1}^2]}{2}\} \tag{6-13}$$

Since α and β are given incentive contract by the central government, they are exogenous variables in the decision-making of the local government. The optimisation problem for the local government is as follows:

$$\max_{n,a_H,a_L,b_H,b_L} E[U_l] \tag{6-14}$$

s.t

IC:

$${e_i}^* = \text{argmax}E(U_{di}) \qquad i \in \{H, L\} \tag{6-15}$$

$$U_{dH}(e_H, a_H, b_H) \geq U_{dH}(e_L, a_L, b_L) \tag{6-16}$$

$$U_{dL}(e_L, a_L, b_L) \geq U_{dL}(e_H, a_H, b_H) \tag{6-17}$$

IR:

$$U_{dH}(e_H, a_H, b_H) \geq U_0 \tag{6-18}$$

$$U_{dL}(e_L, a_L, b_L) \geq U_0 \tag{6-19}$$

The above constraints include the incentive compatibility constraints and participation constraints for developers of different cost types.

Lemma 6.2. In model N, the optimal green effort of the local government is $n^* = \frac{\beta}{\mu}$.

Proof: Same as Lemma 6.1.

Lemma 6.2 indicates that given the incentive contract $\{\alpha, \beta\}$ from the central government, the optimal green effort n^* of the local government depends on the central government's incentive intensity β and the cost coefficient μ of the local government's efforts, and is independent of the central government's fixed payment α.

Corollary 6.2.1. The local government's green effort is positively correlated with the central government's incentive intensity and negatively correlated with its own cost coefficient.

Proof: $\frac{\partial n^*}{\partial \mu} = -\frac{\beta}{\mu^2} < 0$ and $\frac{\partial n^*}{\partial \beta} = \frac{1}{\mu} > 0$.

Corollary 6.2.1 demonstrates that increasing the central government's incentive intensity helps to enhance the local government's green effort, thereby promoting the high-quality development of GBs. This is because the higher the incentive intensity, the more the local government's rewards depend on its own green efforts; the more effort, the greater the reward. Costs, however, are a key factor constraining the local government's green effort. The higher the unit effort cost, the more the local government will reduce green efforts to save costs.

Based on Lemmas 6.1 and 6.2, the local government's optimisation problem can be solved. First, substitute the optimal green effort n^* and e^* into the utility function of the local government. Then, according to Corollary 6.1.3, e.g., the low-cost developer has incentives to misreport, while the high-cost developer receives reservation utility, (6-17) and (6-18) are binding constraints. Therefore, construct the following Lagrangian function:

$L_1(a_H, a_L, b_H, b_L, \xi, \varphi) = \theta\{\alpha + \beta(n^* + \gamma e_L{}^*) - (a_L + b_L\gamma e_L{}^*) - \frac{\mu(n^*)^2}{2} - \frac{\rho_2[\beta^2\sigma_2{}^2 + (\beta - b_L)^2\sigma_1{}^2]}{2}\} + (1-\theta)\{\alpha + \beta(n^* + \gamma e_H{}^*) - (a_H + b_H\gamma e_H{}^*) - \frac{\mu(n^*)^2}{2} - \frac{\rho_2[\beta^2\sigma_2{}^2 + (\beta - b_H)^2\sigma_1{}^2]}{2}\} + \xi\{a_L + b_L\gamma e_L{}^* + p_L - \frac{h_L(e_L{}^*)^2}{2} - \frac{\rho_1 b_L{}^2\sigma_1{}^2}{2} - [a_H + b_H\gamma e_L{}'^* + p_H - \frac{h_L(e_L{}'^*)^2}{2} - \frac{\rho_1 b_H{}^2\sigma_1{}^2}{2}]\} + \varphi[a_H + b_H\gamma e_H{}^* + p_H - \frac{h_H(e_H{}^*)^2}{2} - \frac{\rho_1 b_H{}^2\sigma_1{}^2}{2}]$ (6-20)

Let:

$$\begin{cases} \frac{\partial L_1}{\partial a_H} = 0 \\ \frac{\partial L_1}{\partial a_L} = 0 \\ \frac{\partial L_1}{\partial b_H} = 0 \\ \frac{\partial L_1}{\partial b_L} = 0 \\ \frac{\partial L_1}{\partial \xi} = 0 \\ \frac{\partial L_1}{\partial \varphi} = 0 \end{cases} \tag{6-21}$$

Solve equation (6-21) to obtain Lemma 6.3.

Lemma 6.3. In model N, the optimal incentive contracts set by the local government for high- and low-cost developers are $\{a_H{}^*, b_H{}^*\}$ and $\{a_L{}^*, b_L{}^*\}$, respectively.

Where: $b_H{}^* = \frac{\beta h_L(1-\theta)(\gamma^2 + h_H\rho_2\sigma_1{}^2)}{\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2}$, $b_L{}^* = \frac{\beta(\gamma^2 + h_L\rho_2\sigma_1{}^2)}{\gamma^2 + h_L(\rho_1+\rho_2)\sigma_1{}^2}$,

$a_H{}^* = \frac{h_L{}^2\beta^2(1-\theta)^2(h_H\rho_1\sigma_1{}^2 - \gamma^2)(\gamma^2 + h_H\rho_2\sigma_1{}^2)^2}{2h_H[\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]^2} - p_H$,

$$a_L{}^* = \frac{\beta^2}{2(\rho_1+\rho_2)^3}\{\rho_1\rho_2{}^2(\rho_1+\rho_2)\sigma_1{}^2 - \frac{\gamma^2\rho_2[h_L\rho_2(\rho_1+\rho_2)-2h_H\rho_1{}^2]}{h_H h_L} + \frac{\gamma^4\rho_1(\rho_1{}^2-4\rho_1\rho_2-2\rho_2{}^2)}{h_L[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2]} - \frac{2(h_H-h_L)\gamma^4\rho_2(\rho_1+\rho_2)[(h_H-h_L)\theta\rho_2-h_L(1-\theta)\rho_1]}{h_H h_L[\gamma^2(h_L+h_H\theta-2h_L\theta)+h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]} - \frac{\gamma^6\rho_1{}^2(2\rho_1+\rho_2)}{h_L[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2]^2} + \frac{(h_H-h_L)\gamma^6(\rho_1+\rho_2)[(h_H-h_L)\theta\rho_2-h_L(1-\theta)\rho_1]^2}{h_H h_L[\gamma^2(h_L+h_H\theta-2h_L\theta)+h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]^2}\} - p_L.$$

Lemma 6.3 presents the optimal incentive mechanisms designed by the local government under information asymmetry. Through these optimal incentive contracts, the private information of the developer can be revealed, achieving information sharing while motivating the developer to make maximum green efforts. Under the local government's optimal contracts, the optimal decision for the developer with private cost information is to disclose the true information. In this manner, the developer ensures utility above its reservation utility (participation constraint) and avoids utility loss due to misreported cost information (incentive compatibility constraint). Therefore, the local government's optimal incentive contracts can effectively identify the developer's cost type, promote information sharing and encourage the developer to make reasonable green effort decisions.

Corollary 6.3.1. $b_L{}^* > b_H{}^*$.

Proof: $b_L{}^* - b_H{}^* = \frac{\beta(h_H-h_L)\gamma^2\{\gamma^2\theta+h_L[\rho_1(1-\theta)+\theta\rho_2]\sigma_1{}^2\}}{[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2][(h_H-h_L)\gamma^2\theta+h_L\gamma^2(1-\theta)+h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]} > 0.$

Corollary 6.3.1 indicates that, due to information asymmetry across levels, the optimal incentive mechanism for the local government is to consistently apply higher incentive intensity to the low-cost developer to encourage truthful reporting. Consequently, the low-cost developer exhibits greater efforts towards high-quality GB development.

Corollary 6.3.2. $\frac{\partial b_H{}^*}{\partial \beta} > 0$ and $\frac{\partial b_L{}^*}{\partial \beta} > 0$.

Proof: $\frac{\partial b_H{}^*}{\partial \beta} = \frac{h_L(1-\theta)(\gamma^2+h_H\rho_2\sigma_1{}^2)}{\gamma^2(h_L+h_H\theta-2h_L\theta)+h_Hh_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2} > 0$ and $\frac{\partial b_L{}^*}{\partial \beta} = \frac{(\gamma^2+h_L\rho_2\sigma_1{}^2)}{\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2} > 0$.

Corollary 6.3.2 indicates that the local government's incentive intensity towards developers is influenced by the central government's incentive intensity, showing a positive correlation between them. As the central government increases its incentive intensity, the local government also raises its incentive intensity towards developers, encouraging them to construct higher-quality GBs. This allows the local government to seek more rewards from the central government. Corollary 6.3.2 reveals the indirect incentive effect of the central government's incentive mechanism on developers' green efforts. As suggested by Sun T. (2019), "Superiors' preferences elicit heightened attention and emphasis from subordinates". Under China's MLG structure, the central government's incentive signals play a significant guiding role in local governments' decision-making due to political centralisation.

Corollary 6.3.3. $\frac{b_H{}^*}{\beta} < 1$ and $\frac{b_L{}^*}{\beta} < 1$.

Proof: $\frac{b_H{}^*}{\beta} = \frac{h_L(1-\theta)(\gamma^2+h_H\rho_2\sigma_1{}^2)}{\gamma^2(h_L+h_H\theta-2h_L\theta)+h_Hh_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2} < 1$ and $\frac{b_L{}^*}{\beta} = \frac{(\gamma^2+h_L\rho_2\sigma_1{}^2)}{\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2} < 1$.

Corollary 6.3.3 shows that the local government's incentive intensity towards developers consistently remains lower than the central government's incentive intensity towards the local government. Despite the local government's willingness to increase its incentive intensity, it always remains lower as the central government's incentive intensity rises. This downward intensity transfer is due to the local government's risk aversion and the dual uncertainty it faces regarding the green efforts of developers and its own green efforts. As a result, the local government does not fully pass on the incentives received from the central government to developers. Instead, it redistributes them based on factors such as risk aversion, developer costs and market disturbances. Similar findings were observed in the study of Y. Zhou (2015), indicating the disappearance of subsidies across different levels of government.

6.3.3 Optimal strategy of the central government

As the pure principal, the central government's decision variables are α and β provided to the local government. The certainty equivalent profit of the risk-neutral central government comprises environmental benefits and incentive expenditures to the agent:

$$E(\pi_c) = (1-\beta)\pi_e - \alpha = (1-\beta)[n + \gamma(\theta e_L + (1-\theta)e_H)] - \alpha \tag{6-22}$$

The central government's optimisation problem is as follows:

$$\max_{\alpha,\beta} E[\pi_c] \tag{6-23}$$

s.t.

IC: $${a_H}^*, {b_H}^*, {a_L}^*, {b_L}^*, n^*, {e_H}^*, {e_L}^* \tag{6-24}$$

IR: $$U_l \geq U_0 \tag{6-25}$$

Where IC is the incentive compatibility constraint, and IR is the participation constraint for the local government. Based on the participation constraint of the local government and the first-order condition of the central government's certainty equivalent profit with respect to β, Lemma 6.4 can be derived.

Lemma 6.4. In model N, the central government's optimal incentive contract set for the local government is $\{\alpha^*, \beta^*\}$.

$$\text{Where: } \beta^* = \frac{\begin{gathered} {h_L}^2\gamma^4(1-\theta)^2\mu\left[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2\right]+{h_H}^2\left[\gamma^2\theta+h_L(1-\theta)(\rho_1+\rho_2){\sigma_1}^2\right] \\ \left[\gamma^4\theta\mu+{h_L}^2(\rho_1+\rho_2){\sigma_1}^2+h_L\gamma^2\left(1+\theta\mu\rho_2{\sigma_1}^2\right)\right]+h_Hh_L\gamma^2\{\gamma^4(1-2\theta)\theta\mu+ \\ {h_L}^2(\rho_1+\rho_2){\sigma_1}^2[1-2\theta+(1-\theta)^2\mu\rho_2{\sigma_1}^2]+h_L\gamma^2[1-2\theta+(1-\theta-\theta^2]\mu\rho_2{\sigma_1}^2)\} \end{gathered}}{\begin{gathered} {h_L}^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2]+h_Hh_L\gamma^2(1-2\theta) \\ \begin{Bmatrix} \gamma^4\theta\mu+h_L\gamma^2[1+\mu\rho_2({\sigma_1}^2+{\sigma_2}^2)]+ \\ {h_L}^2{\sigma_1}^2[\rho_1+\rho_2\rho_2+\mu\rho_1\rho_2({\sigma_1}^2+{\sigma_2}^2)+\mu{\rho_2}^2({\sigma_1}^2-\theta{\sigma_1}^2-{\sigma_2}^2)] \end{Bmatrix}+ \\ {h_H}^2\begin{Bmatrix} \gamma^6\theta^2\mu+h_L\gamma^4\theta[1+\mu(\rho_1-\theta\rho_1+2\rho_2-\theta\rho_2){\sigma_1}^2+\mu\rho_2{\sigma_2}^2]+ \\ {h_L}^3(1-\theta)(\rho_1+\rho_2){\sigma_1}^4[\rho_1+\rho_2+\mu\rho_1\rho_2{\sigma_1}^2+\mu\rho_2(\rho_1+\rho_2){\sigma_2}^2]+ \\ {h_L}^2\gamma^2{\sigma_1}^2[\rho_1+\rho_2+\mu\rho_1\rho_2({\sigma_1}^2+{\sigma_2}^2)+\mu{\rho_2}^2(2(1-\theta)\theta{\sigma_1}^2-{\sigma_2}^2)] \end{Bmatrix} \end{gathered}},$$

$$\alpha^* = \frac{\begin{gathered} {h_L}^2(\beta^*)^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2](\beta^*)^2\gamma^6\theta^2\mu+ \\ {h_H}^2\left\{\begin{gathered} {h_L}^2\gamma^2{\sigma_1}^2\begin{bmatrix} 2p_L\theta\mu(\rho_1+\rho_2)+(\beta^*)^2 \\ (\rho_1+\rho_2-(1-2(1-\theta)\theta)\mu\rho_1\rho_2{\sigma_1}^2-\mu\rho_2(\rho_1+\rho_2){\sigma_2}^2) \end{bmatrix}+ \\ {h_L}^3(1-\theta)\left(\rho_1+\rho_2\right){\sigma_1}^4[2p_L\theta\mu(\rho_1+\rho_2)+ \\ (\beta^*)^2\left(1-\mu\rho_2{\sigma_2}^2\right)(\rho_1+\rho_2)-(\beta^*)^2\mu\rho_1\rho_2{\sigma_1}^2]+ \\ h_L\gamma^4\theta[2p_L\theta\mu+(\beta^*)^2\left(1+(1-\theta)\mu\rho_1{\sigma_1}^2+\mu\rho_2(\theta{\sigma_1}^2-{\sigma_2}^2)\right)] \end{gathered}\right\}+h_Hh_L\gamma^2 \\ \left\{\begin{gathered} (\beta^*)^2\gamma^4(1-2\theta)\theta\mu+h_L\gamma^2\begin{bmatrix} 2p_L(1-2\theta)\theta\mu+(\beta^*)^2 \\ \left(1+\mu\rho_2{\sigma_1}^2-2\theta\left(1+\theta\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2\right) \end{bmatrix}+ \\ {h_L}^2{\sigma_1}^2\begin{bmatrix} 2p_L\theta(1-2\theta)\mu(\rho_1+\rho_2)+(\beta^*)^2(\rho_2\left(1+\mu\rho_2{\sigma_1}^2-\theta(2+\mu\rho_2{\sigma_1}^2)-(1-2\theta)\mu\rho_2{\sigma_2}^2\right)+ \\ \rho_1(1+\mu\rho_2{\sigma_1}^2-2\theta\left(1+(1-\theta)\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2) \end{bmatrix} \end{gathered}\right\} \end{gathered}}{2h_Hh_L\mu[\gamma^4(2h_L\theta-h_L-h_H\theta)-h_L\gamma^2(h_H+h_L-2h_L\theta)(\rho_1+\rho_2){\sigma_1}^2-h_H{h_L}^2(1-\theta)(\rho_1+\rho_2)^2{\sigma_1}^4]} - p_H(1-\theta)\,.$$

Proof: By $U_l = U_0$, we obtain:

$$\alpha = \frac{\begin{gathered} {h_L}^2\beta^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2]\beta^2\gamma^6\theta^2\mu+ \\ {h_H}^2\left\{\begin{gathered} {h_L}^2\gamma^2{\sigma_1}^2\begin{bmatrix} 2p_L\theta\mu(\rho_1+\rho_2)+\beta^2 \\ (\rho_1+\rho_2-(1-2(1-\theta)\theta)\mu\rho_1\rho_2{\sigma_1}^2-\mu\rho_2(\rho_1+\rho_2){\sigma_2}^2) \end{bmatrix}+ \\ {h_L}^3(1-\theta)(\rho_1+\rho_2){\sigma_1}^4[2p_L\theta\mu(\rho_1+\rho_2)+ \\ \beta^2\left(1-\mu\rho_2{\sigma_2}^2\right)(\rho_1+\rho_2)-\beta^2\mu\rho_1\rho_2{\sigma_1}^2]+ \\ h_L\gamma^4\theta[2p_L\theta\mu+(\beta^*)^2\left(1+(1-\theta)\mu\rho_1{\sigma_1}^2+\mu\rho_2(\theta{\sigma_1}^2-{\sigma_2}^2)\right)] \end{gathered}\right\}+h_Hh_L\gamma^2 \\ \left\{\begin{gathered} \beta^2\gamma^4(1-2\theta)\theta\mu+h_L\gamma^2\begin{bmatrix} 2p_L(1-2\theta)\theta\mu+\beta^2 \\ \left(1+\mu\rho_2{\sigma_1}^2-2\theta\left(1+\theta\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2\right) \end{bmatrix}+ \\ {h_L}^2{\sigma_1}^2\begin{bmatrix} 2p_L\theta(1-2\theta)\mu(\rho_1+\rho_2)+\beta^2(\rho_2\left(1+\mu\rho_2{\sigma_1}^2-\theta(2+\mu\rho_2{\sigma_1}^2)-(1-2\theta)\mu\rho_2{\sigma_2}^2\right)+ \\ \rho_1(1+\mu\rho_2{\sigma_1}^2-2\theta\left(1+(1-\theta)\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2) \end{bmatrix} \end{gathered}\right\} \end{gathered}}{2h_Hh_L\mu[\gamma^4(2h_L\theta-h_L-h_H\theta)-h_L\gamma^2(h_H+h_L-2h_L\theta)(\rho_1+\rho_2){\sigma_1}^2-h_H{h_L}^2(1-\theta)(\rho_1+\rho_2)^2{\sigma_1}^4]} - p_H(1-\theta)\ .$$

Substitute α into $E(\pi_c)$, set the first derivative $\frac{\partial E(\pi_c)}{\partial \beta} = 0$, and obtain β^*. Substitute β^* back into α to obtain the optimal α^*.

Lemma 6.4 indicates that, in the absence of collusion, the central government must consider multiple factors when designing the optimal incentive mechanism for the local government. These factors include the cost coefficient of local government's green efforts μ and its risk aversion level ρ_2, the probability distribution of the cost types of developers and their risk aversion level ρ_1, the green effort cost coefficient h_i of different types of developers, their effort output coefficient γ and external random factors. Furthermore, the central government must consider the sales price of GBs to determine the optimal fixed payment. Due to the complexity of the analytical formula, the impact of each factor on the optimal incentive mechanism will be further discussed in the numerical simulation section.

6.3.4 Optimal payoffs of each party and social welfare

Proposition 6.1. In model N, under the optimal incentive mechanism:

(1) The central government's optimal benefit is $\pi_c{}^* = (1-\beta^*)[n^* + \gamma\theta e_L{}^* + \gamma(1-\theta)e_H{}^*] - \alpha^*$;

(2) The local government's optimal utility is $U_l{}^* = U_0 = 0$;

(3) The high-cost developer's optimal utility is $U_{dH}{}^* = U_0 = 0$; the low-cost developer's optimal utility is

$$U_{dL}{}^* = \frac{\begin{array}{c}(h_H-h_L)h_L\gamma^2(1-\theta)^2\left(\gamma^2+h_H\rho_2\sigma_1{}^2\right)^2 \\ \left\{\begin{array}{c} h_L{}^2\gamma^4(1-\theta)^2\mu\left[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2\right]+h_H{}^2\left[\gamma^2\theta+h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2\right] \\ \left[\gamma^4\theta\mu+h_L{}^2(\rho_1+\rho_2)\sigma_1{}^2+h_L\gamma^2(1+\theta\mu\rho_2\sigma_1{}^2)\right] \\ +h_Hh_L\gamma^2\left[\begin{array}{c}\gamma^4(1-2\theta)\theta\mu+h_L{}^2(\rho_1+\rho_2)\sigma_1{}^2\left(1-2\theta+(1-\theta)^2\mu\rho_2\sigma_1{}^2\right) \\ +h_L\gamma^2(1-2\theta-(\theta+\theta^2-1)\mu\rho_2\sigma_1{}^2)\end{array}\right]\end{array}\right\}^2\end{array}}{\begin{array}{c}2h_H[\gamma^2(h_L+h_H\theta-2h_L\theta)+h_Hh_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]^2 \\ \left\{\begin{array}{c} h_L{}^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1{}^2]+h_Hh_L\gamma^2(1-2\theta)[\gamma^4\theta\mu+h_L\gamma^2\left(1+\mu\rho_2(\sigma_1{}^2+\sigma_2{}^2)\right) \\ +h_L{}^2\sigma_1{}^2(\rho_1+\rho_2+\mu\rho_1\rho_2(\sigma_1{}^2+\sigma_2{}^2)-\mu\rho_2{}^2((1-\theta)\sigma_1{}^2+\sigma_2{}^2))] \\ +h_H{}^2[\gamma^6\theta^2\mu+h_L\gamma^4\theta(1+\mu(\rho_1-\theta\rho_1+2\rho_2-\theta\rho_2)\sigma_1{}^2+\mu\rho_2\sigma_2{}^2) \\ +h_L{}^3(1-\theta)(\rho_1+\rho_2)\sigma_1{}^4(\rho_1+\rho_2+\mu\rho_1\rho_2\sigma_1{}^2+\mu\rho_2(\rho_1+\rho_2)\sigma_2{}^2) \\ +h_L{}^2\gamma^2\sigma_1{}^2(\rho_1+\rho_2+\mu\rho_1\rho_2(\sigma_1{}^2+\sigma_2{}^2)+\mu\rho_2{}^2(2(1-\theta)\theta\sigma_1{}^2+\sigma_2{}^2))]\end{array}\right\}^2\end{array}};$$

(4) Considering that social welfare is the sum of the principal's and the agent's welfare (X. Yang et al., 2021), the social welfare is $W^* = \pi_c{}^* + U_l{}^* + U_{dH}{}^* + U_{dL}{}^*$.

Proof: By substituting the optimal results from Lemma 6.4 back into the optimal decisions of the local government and the developer, we can derive the optimal strategies for each party, thereby calculating the optimal benefit and utilities for each party.

Proposition 6.1 reveals that, in the absence of collusion, the optimal incentive mechanism yields strictly positive returns for the central government as the "pure principal". However, the local government, acting as the "intermediary", and the "pure agent" high-cost developer only achieves retained utility. Conversely, the low-cost developer obtains additional utility. This difference represents the "information rent" (Laffont & Martimort, 2002) paid by the local government to acquire accurate cost information from the developer, stemming from the developer's informational advantage. Myerson (1979) implies that the low-cost developer has an incentive to misreport its true cost types. Consequently, if the low-cost developer cannot acquire any information rent, it may withhold its true information and opt for a contract with the high-cost developer. Additionally, when the developer chooses high-cost options within incentive contracts, its motivation for green efforts diminishes. Consequently, the local government evaluates such a developer unfavourably, leading to lower incentive intensities and retained utility. Conversely, the local government rewards low-cost "outstanding" developers for promoting high-quality green construction.

Corollary 6.1. When $\theta = 1$, the low-cost developer obtains the reservation utility.

Corollary 6.1 indicates that when the market consists entirely of low-cost developers, the developer's informational advantage regarding the costs disappears. This implies that the local government no longer needs to pay the corresponding information rent. In this scenario, the optimal incentive mechanism only needs to ensure the developer's reservation utility.

6.4 Incentive Mechanisms under Collusion (Model C)

In China's MLG context, local governments may be captured by local enterprises to increase fiscal revenues, resulting in the moral hazard of collusion between the two parties (Li Y. et al., 2019; Xiao Z. et al., 2020). Specifically in GB promotion, moral hazards of collusion involving exaggeration and misrepresentation of the environmental benefits of GB projects may exist. To address this, this section proposes an incentive mechanism for the case of local government–developer collusion.

Building upon existing theoretical analyses of collusion equilibrium (Faure-Grimaud et al., 2003) and the research conducted by X. Yang et al. (2021), this section assumes that due to collusion between the local government and developer, an overstatement factor exists, denoted as m for the environmental benefits. To prevent collusion, the central government conducts periodic inspections and imposes penalties on local government officials (such as fines or dismissals). The severity of the penalties is linearly related to the degree of collusion between the local government and developer, denoted as βm, with the penalty for collusion being represented as $f = \lambda(\beta m)^2/2$.

By incorporating the degree of collusion and collusion penalties into the model in Section 6.3, this section constructs an incentive model for the situation involving collusion. The incentive model is formulated as follows:

$$\max_{\alpha,\beta} E[\pi_c] \tag{6-26}$$

s.t.

IC：

$$e_i^{**} = \text{argmax} E(U_{di}) \quad i \in \{H, L\} \tag{6-27}$$

$$n^{**}, a_i^{**}, b_i^{**}, m^{**} = \text{argmax} E(U_l) \quad i \in \{H, L\} \tag{6-28}$$

$$U_{dH}(e_H, a_H, b_H) \geq U_{dH}(e_L, a_L, b_L) \tag{6-29}$$

$$U_{dL}(e_L, a_L, b_L) \geq U_{dL}(e_H, a_H, b_H) \tag{6-30}$$

IR：

$$U_{dH}(e_H, a_H, b_H) \geq U_0 \tag{6-31}$$

$$U_{dL}(e_L, a_L, b_L) \geq U_0 \tag{6-32}$$

$$U_l \geq U_0 \tag{6-33}$$

Where π_c, U_l and U_{di} represent the revenue of the risk-neutral central government, and the utility of the risk-averse local government and developer, respectively, in a collusion scenario. $\{\alpha, \beta\}$ denote the incentive contract designed by the central government, while $\{a_H, b_H\}$ and $\{a_L, b_L\}$ represent the incentive contracts designed by the local government. Equations (6-31), (6-32) and (6-33) ensure that the developer and local government, under collusion, accept incentive contracts if the utility exceeds their reserved utility U_0, otherwise, they reject the contract. Equations (6-27) and (6-28) ensure incentive compatibility under moral hazard, optimising green efforts for the developer and local government. Equations (6-29) and (6-30) establish incentive compatibility for the developer under adverse selection, ensuring expected utility of incentive contract $\{a_H, b_H\}$ ($\{a_L, b_L\}$) for high-cost (low-cost) developers is not lower than that of incentive contract $\{a_L, b_L\}$ ($\{a_H, b_H\}$), promoting truthful choices based on individual costs and achieving information disclosure goals. Similar to model N, based on the established incentive model and the decision sequence of the three parties, Sections 6.4.1 to 6.4.3 solve and analyse the optimal strategies of each stakeholder through backward induction.

6.4.1 Optimal strategy of the developer

The utility of the risk-averse developer in a collusion scenario is given by:

$$U_{di} = \mathrm{E}(\pi_{di}) - \frac{\rho_1 {b_i}^2 {\sigma_1}^2}{2} \qquad i \in \{H, L\} \tag{6-34}$$

Based on this, Lemma 6.5 can be derived.

Lemma 6.5. In model N, the optimal green effort of the high-cost (low-cost) developer, who truthfully chooses the high-cost (low-cost) contract is ${e_H}^{**} = \frac{b_H \gamma}{h_H}$ and ${e_L}^{**} = \frac{b_L \gamma}{h_L}$, respectively. The optimal green effort of the high-cost (low-cost) developer, who misreports its cost type and chooses the low-cost (high-cost) contract is ${e_H}'^{**} = \frac{b_L \gamma}{h_H}$ and ${e_L}'^{**} = \frac{b_H \gamma}{h_L}$, respectively.

Proof: Same as Lemma 6.1.

Corollary 6.5.1. The developer's optimal green effort ${e_i}^{**}$ is positively correlated with the local government's incentive intensity b_i and the GB greenness output coefficient γ, and negatively correlated with its cost coefficient h_i.

Proof: Same as Corollary 6.1.1.

Corollary 6.5.1 indicates that in the context of local government–developer collusion, an increase in incentive intensity by the local government also contributes to enhancing the green efforts of the developer, thereby elevating the quality of GBs. Cost, likewise, serves as a pivotal factor constraining the green effort of the developer. Developers with higher per-unit effort costs tend to reduce their green efforts to mitigate the associated high costs.

Corollary 6.5.2. The green effort of a low-cost developer is always at least equal to that of a high-cost developer.

Proof: Same as Corollary 6.1.2.

Corollary 6.5.3. The low-cost developer is motivated to misreport its cost type and pretends to be a high-cost developer. Conversely, the high-cost developer has no incentive to misreport its cost type and always reports its cost type truthfully.

Proof: Same as Corollary 6.1.3.

6.4.2 Optimal strategy of the local government

In the collusion scenario, in order to obtain greater rewards, the local government colludes the developer to overreport environmental benefits, but they also face penalties from the central government. Therefore, the utility of the local government can be expressed as:

$$U_l = \theta\{\alpha + \beta(n + \gamma e_L + m) - (a_L + b_L\gamma e_L) - \frac{\mu n^2}{2} - \frac{\lambda(\beta m)^2}{2} - \frac{\rho_2[\beta^2{\sigma_2}^2+(\beta-b_L)^2{\sigma_1}^2]}{2}\} + (1-\theta)\{\alpha + \beta(n + \gamma e_H + m) - (a_H + b_H\gamma e_H) - \frac{\mu n^2}{2} - \frac{\lambda(\beta m)^2}{2} - \frac{\rho_2[\beta^2{\sigma_2}^2+(\beta-b_H)^2{\sigma_1}^2]}{2}\} \quad (6\text{-}35)$$

The optimisation problem for the local government is as follows:

$$\max_{n,m,a_H,a_L,b_H,b_L} E[U_l] \quad (6\text{-}36)$$

s.t

IC: $${e_i}^{**} = \text{argmax}E(U_{di}) \qquad i \in \{H, L\} \quad (6\text{-}37)$$

$$U_{dH}(e_H, a_H, b_H) \geq U_{dH}(e_L, a_L, b_L) \quad (6\text{-}38)$$

$$U_{dL}(e_L, a_L, b_L) \geq U_{dL}(e_H, a_H, b_H) \quad (6\text{-}39)$$

IR: $$U_{dH}(e_H, a_H, b_H) \geq U_0 \quad (6\text{-}40)$$

$$U_{dL}(e_L, a_L, b_L) \geq U_0 \quad (6\text{-}41)$$

The above constraints include the incentive compatibility constraints and participation constraints for developers of different cost types.

Lemma 6.6. In model C, the local government's optimal green effort and overreported environmental benefits are $n^* = \frac{\beta}{\mu}$ and $m^{**} = \frac{1}{\lambda\beta}$, respectively.

Proof: Same as Lemma 6.1.

Corollary 6.6.1. The local government's green effort is positively correlated with the central government's incentive intensity and negatively correlated with its own cost coefficient. The local government's overreported environmental benefits are negatively correlated with the incentive intensity and penalty coefficient enforced by the central government.

Proof: $\frac{\partial n^{**}}{\partial \mu} = -\frac{\beta}{\mu^2} < 0$, $\frac{\partial n^{**}}{\partial \beta} = \frac{1}{\mu} > 0$, $\frac{\partial m^{**}}{\partial \beta} = \frac{1}{\lambda \beta^2} < 0$ and $\frac{\partial m^{**}}{\partial \lambda} = \frac{1}{\lambda^2} < 0$.

Corollary 6.6.1 highlights the beneficial impact of the central government's increased incentive intensity on promoting the green efforts of the local government and curbing collusion. Specifically, elevating the incentive intensity facilitates the local government's engagement in green endeavours. This is attributed to the heightened incentive intensity, which renders the transfer payments received by the local government more reliant on its own green efforts. Consequently, the local government is motivated to drive the high-quality development of GBs to secure greater transfer payments. Moreover, higher incentive intensity intensifies the penalties faced upon collusion detection, prompting the local government to exercise greater caution in overly reporting environmental benefits. Additionally, cost considerations also constrain the green efforts of the local government, as higher per-unit effort costs lead to a reduction in green endeavours in light of economic considerations.

Based on Lemmas 6.5 and 6.6, the local government's optimisation problem can be solved. First, substitute the optimal green effort n^{**} and e^{**} along with the overreported environmental benefits m^{**} into the utility function of the local government. Then, according to Corollary 6.5.3, e.g., the low-cost developer has incentives to misreport, while the high-cost developer receives reservation utility, (6-39) and (6-40) are binding constraints. Therefore, construct the following Lagrangian function:

$$L_2(a_H, a_L, b_H, b_L, \omega, \eta) = \theta\{\alpha + \beta(n + \gamma e_L{}^{**} + m) - (a_L + b_L\gamma e_L{}^{**}) - \frac{\mu(n^{**})^2}{2} - \frac{\lambda(\beta m^{**})^2}{2} - \frac{\rho_2[\beta^2\sigma_2{}^2 + (\beta - b_L)^2\sigma_1{}^2]}{2}\} + (1-\theta)\{\alpha + \beta(n + \gamma e_H{}^{**} + m) - (a_H + b_H\gamma e_H{}^{**}) - \frac{\mu(n^{**})^2}{2} - \frac{\lambda(\beta m^{**})^2}{2} - \frac{\rho_2[\beta^2\sigma_2{}^2 + (\beta - b_H)^2\sigma_1{}^2]}{2}\} + \omega\{a_L + b_L\gamma e_L{}^{**} + p_L - \frac{h_L(e_L{}^*)^2}{2} - \frac{\rho_1 b_L{}^2\sigma_1{}^2}{2} - [a_H + b_H\gamma e_L{}'^{**} + p_H - \frac{h_L(e_L{}'^{**})^2}{2} - \frac{\rho_1 b_H{}^2\sigma_1{}^2}{2}]\} + \eta[a_H + b_H\gamma e_H{}^{**} + p_H - \frac{h_H(e_H{}^{**})^2}{2} - \frac{\rho_1 b_H{}^2\sigma_1{}^2}{2}] \tag{6-42}$$

Let:

$$\begin{cases} \dfrac{\partial L_2}{\partial a_H} = 0 \\ \dfrac{\partial L_2}{\partial a_L} = 0 \\ \dfrac{\partial L_2}{\partial b_H} = 0 \\ \dfrac{\partial L_2}{\partial b_L} = 0 \\ \dfrac{\partial L_2}{\partial \omega} = 0 \\ \dfrac{\partial L_2}{\partial \eta} = 0 \end{cases} \tag{6-43}$$

Solve equation (6-43) to obtain Lemma 6.7.

Lemma 6.7. In model C, the optimal incentive contracts set by the local government for high- and low-cost developers are $\{a_H{}^{**}, b_H{}^{**}\}$ and $\{a_L{}^{**}, b_L{}^{**}\}$, respectively.

Where: $b_H{}^{**} = \frac{\beta h_L(1-\theta)(\gamma^2 + h_H\rho_2\sigma_1{}^2)}{\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2}$, $b_L{}^{**} = \frac{\beta(\gamma^2 + h_L\rho_2\sigma_1{}^2)}{\gamma^2 + h_L(\rho_1+\rho_2)\sigma_1{}^2}$,

$$a_H{}^{**} = \frac{h_L{}^2\beta^2(1-\theta)^2(h_H\rho_1\sigma_1{}^2 - \gamma^2)(\gamma^2 + h_H\rho_2\sigma_1{}^2)^2}{2h_H[\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]^2} - p_H,$$

$$a_L{}^{**} = \frac{\beta^2}{2(\rho_1+\rho_2)^3}\{\rho_1\rho_2{}^2(\rho_1+\rho_2)\sigma_1{}^2 + \frac{\gamma^4\rho_1(\rho_1{}^2 - 4\rho_1\rho_2 - 2\rho_2{}^2)}{h_L[\gamma^2 + h_L(\rho_1+\rho_2)\sigma_1{}^2]} - \frac{\gamma^2\rho_2[h_L\rho_2(\rho_1+\rho_2) - 2h_H\rho_1{}^2]}{h_H h_L} + \frac{(h_H - h_L)\gamma^6(\rho_1+\rho_2)[(h_H-h_L)\theta\rho_2 - h_L(1-\theta)\rho_1]^2}{h_H h_L(\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2)^2} - \frac{\gamma^6\rho_1{}^2(2\rho_1+\rho_2)}{h_L[\gamma^2 + h_L(\rho_1+\rho_2)\sigma_1{}^2]^2} - \frac{2(h_H-h_L)\gamma^4\rho_2(\rho_1+\rho_2)[(h_H-h_L)\theta\rho_2 - h_L(1-\theta)\rho_1]}{h_H h_L[\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2)\sigma_1{}^2]}\} - p_L.$$

Lemma 6.7 presents the optimal incentive mechanisms designed by the local government under information asymmetry in the collusion scenario. These mechanisms foster information sharing while incentivising developers to maximise their green efforts.

Corollary 6.7.1. ${b_L}^{**} > {b_H}^{**}$.

Proof: ${b_L}^{**} - {b_H}^{**} = \frac{\beta(h_H - h_L)\gamma^2\{\gamma^2\theta + h_L[\rho_1(1-\theta)+\theta\rho_2]{\sigma_1}^2\}}{[\gamma^2 + h_L(\rho_1+\rho_2){\sigma_1}^2][(h_H-h_L)\gamma^2\theta + h_L\gamma^2(1-\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2){\sigma_1}^2]} > 0$.

Corollary 6.7.1 demonstrates that due to the existence of information asymmetry between hierarchical levels, the local government, in the collusion scenario, will also adopt incentive mechanisms that provide higher incentive intensity to the low-cost developer to induce it to disclose true cost information. These incentive mechanisms effectively promote the low-cost developer to more actively engage in the high-quality development of GBs.

Corollary 6.7.2. $\frac{\partial {b_H}^{**}}{\partial \beta} > 0$ and $\frac{\partial {b_L}^{**}}{\partial \beta} > 0$.

Proof: $\frac{\partial {b_H}^{**}}{\partial \beta} = \frac{h_L(1-\theta)(\gamma^2 + h_H\rho_2{\sigma_1}^2)}{\gamma^2(h_L + h_H\theta - 2h_L\theta) + h_H h_L(1-\theta)(\rho_1+\rho_2){\sigma_1}^2} > 0$ and $\frac{\partial {b_L}^{**}}{\partial \beta} = \frac{(\gamma^2 + h_L\rho_2{\sigma_1}^2)}{\gamma^2 + h_L(\rho_1+\rho_2){\sigma_1}^2} > 0$.

In the collusion scenario, similar to the non-collusion scenario, as the central government increases the incentive intensity for the local government, the local government is also willing to increase the incentive intensity for developers to encourage them to more actively engage in high-quality GB construction, thereby striving for more rewards from the central government.

Corollary 6.7.3. $\frac{{b_H}^{**}}{\beta} < 1$ and $\frac{{b_L}^{**}}{\beta} < 1$.

Proof: $\frac{{b_H}^{**}}{\beta} = \frac{h_L(1-\theta)(\gamma^2+h_H\rho_2{\sigma_1}^2)}{\gamma^2(h_L+h_H\theta-2h_L\theta)+h_Hh_L(1-\theta)(\rho_1+\rho_2){\sigma_1}^2} < 1$ and $\frac{{b_L}^{**}}{\beta} = \frac{(\gamma^2+h_L\rho_2{\sigma_1}^2)}{\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2} < 1$.

In the collusion scenario, similar to the non-collusion scenario, although the local government is willing to increase the incentive intensity for developers as the central government increases the incentive intensity for the local government, the incentive intensity will always be less than the central government's.

6.4.3 Optimal strategy of the central government

In the collusion scenario, the central government needs to incur additional expenditures as rewards that do not generate any environmental benefits due to the local government's false reporting of environmental benefits. Meanwhile, due to the central government's supervision, it can also obtain penalty benefits from the local government. Therefore, the certainty equivalent utility of the risk-neutral central government is:

$$E(\pi_c) = (1-\beta)\pi_e - \beta m - \alpha + f = (1-\beta)[n + \gamma(\theta e_L + (1-\theta)e_H)] - \beta m - \alpha + \frac{\lambda\beta^2 m^2}{2} \tag{6-44}$$

The central government's optimisation problem is as follows:

$$\max_{\alpha,\beta} E[\pi_c] \tag{6-45}$$

s.t.

IC: $${a_H}^{**}, {b_H}^{**}, {a_L}^{**}, {b_L}^{**}, m^{**}, n^{**}, {e_H}^{**}, {e_L}^{**} \tag{6-46}$$

IR: $$U_l \geq U_0 \tag{6-47}$$

Where IC is the incentive compatibility constraint, and IR is the participation constraint for the local government. Based on the participation constraint of the local government and the first-order condition of the central government's certainty equivalent profit with respect to β, Lemma 6.8 can be derived.

Lemma 6.8. In model C, the central government's optimal incentive contract set for the local government is $\{\alpha^{**}, \beta^{**}\}$.

$$\text{Where: } \beta^{**} = \frac{\begin{gathered} {h_L}^2\gamma^4(1-\theta)^2\mu\left[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2\right]+{h_H}^2\left[\gamma^2\theta+h_L(1-\theta)(\rho_1+\rho_2){\sigma_1}^2\right] \\ \left[\gamma^4\theta\mu+{h_L}^2(\rho_1+\rho_2){\sigma_1}^2+h_L\gamma^2\left(1+\theta\mu\rho_2{\sigma_1}^2\right)\right]+h_H h_L\gamma^2\{\gamma^4(1-2\theta)\theta\mu+ \\ {h_L}^2(\rho_1+\rho_2){\sigma_1}^2[1-2\theta+(1-\theta)^2\mu\rho_2{\sigma_1}^2]+h_L\gamma^2[1-2\theta+(1-\theta-\theta^2]\mu\rho_2{\sigma_1}^2)\} \end{gathered}}{{h_L}^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2]+h_H h_L\gamma^2(1-2\theta)},$$

$$\begin{gathered} \left\{\begin{gathered} \gamma^4\theta\mu+h_L\gamma^2[1+\mu\rho_2({\sigma_1}^2+{\sigma_2}^2)]+ \\ {h_L}^2{\sigma_1}^2[\rho_1+\rho_2\rho_2+\mu\rho_1\rho_2({\sigma_1}^2+{\sigma_2}^2)+\mu{\rho_2}^2({\sigma_1}^2-\theta{\sigma_1}^2-{\sigma_2}^2)] \end{gathered}\right\}+ \\ {h_H}^2\left\{\begin{gathered} \gamma^6\theta^2\mu+h_L\gamma^4\theta[1+\mu(\rho_1-\theta\rho_1+2\rho_2-\theta\rho_2){\sigma_1}^2+\mu\rho_2{\sigma_2}^2]+ \\ {h_L}^3(1-\theta)(\rho_1+\rho_2){\sigma_1}^4[\rho_1+\rho_2+\mu\rho_1\rho_2{\sigma_1}^2+\mu\rho_2(\rho_1+\rho_2){\sigma_2}^2]+ \\ {h_L}^2\gamma^2{\sigma_1}^2[\rho_1+\rho_2+\mu\rho_1\rho_2({\sigma_1}^2+{\sigma_2}^2)+\mu{\rho_2}^2(2(1-\theta)\theta{\sigma_1}^2-{\sigma_2}^2)] \end{gathered}\right\} \end{gathered}$$

$$\alpha^{**} = \frac{\begin{gathered} {h_L}^2(\beta^{**})^2\gamma^4(1-\theta)^2\lambda\mu\left[\gamma^2+h_L(\rho_1+\rho_2){\sigma_1}^2\right]+ \\ {h_H}^2\left\{\begin{gathered} (\beta^{**})^2\gamma^6\theta^2\lambda\mu+{h_L}^2\gamma^2{\sigma_1}^2[(1+2p_L\theta\lambda)\mu(\rho_1+\rho_2)+ \\ (\beta^{**})^2\lambda\left(\rho_1+\rho_2-(1-2(1-\theta)\theta)\mu\rho_1\rho_2{\sigma_1}^2-\mu\rho_2(\rho_1+\rho_2){\sigma_2}^2\right)] \\ +{h_L}^3(1-\theta)(\rho_1+\rho_2){\sigma_1}^4\left[\begin{gathered} (1+2p_L\theta\lambda)\mu(\rho_1+\rho_2)+ \\ (\beta^{**})^2\lambda\left(1-\mu\rho_2{\sigma_2}^2\right)(\rho_1+\rho_2)-(\beta^{**})^2\mu\rho_1\rho_2{\sigma_1}^2 \end{gathered}\right]+ \\ h_L\gamma^4\theta[(1+2p_L\theta\lambda)\mu+(\beta^{**})^2\lambda\left(1+(1-\theta)\mu\rho_1{\sigma_1}^2+\mu\rho_2\left(\theta{\sigma_1}^2-{\sigma_2}^2\right)\right)] \end{gathered}\right\}+ \\ h_H h_L\gamma^2\left\{\begin{gathered} (\beta^{**})^2\gamma^4(1-2\theta)\theta\lambda\mu+h_L\gamma^2\left[\begin{gathered} (1+2p_L\theta\lambda)(1-2\theta)\mu+(\beta^{**})^2\lambda \\ \left(1+\mu\rho_2{\sigma_1}^2-2\theta\left(1+\theta\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2\right) \end{gathered}\right]+ \\ {h_L}^2{\sigma_1}^2\left[\begin{gathered} (1+2p_L\theta\lambda)(1-2\theta)\mu(\rho_1+\rho_2)+(\beta^{**})^2\lambda \\ (\rho_2\left(1+\mu\rho_2{\sigma_1}^2-\theta\left(2+\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2\right)+ \\ \rho_1(1+\mu\rho_2{\sigma_1}^2-2\theta\left(1+(1-\theta)\mu\rho_2{\sigma_1}^2\right)-(1-2\theta)\mu\rho_2{\sigma_2}^2)) \end{gathered}\right] \end{gathered}\right\} \end{gathered}}{2h_H h_L\lambda\mu[\gamma^4(2h_L\theta-h_L-h_H\theta)-h_L\gamma^2(h_H+h_L-2h_L\theta)(\rho_1+\rho_2){\sigma_1}^2-h_H{h_L}^2(1-\theta)(\rho_1+\rho_2)^2{\sigma_1}^4]} - p_H(1-\theta).$$

Proof: Same as Lemma 6.4.

Lemma 6.8 indicates that in the scenario of local government–developer collusion, the optimal incentive mechanism design of the central government similarly needs to comprehensively consider the cost coefficient of local government's green efforts μ and its risk aversion level ρ_2, the probability distribution of the cost types of developers and their risk aversion level ρ_1, the green effort cost coefficient h_i of different types of developers, their effort output coefficient γ and external random factors. Different from the non-collusion scenario, when considering collusion, the central government's optimal fixed payment needs to comprehensively consider the penalty coefficient for collusion. Due to the complexity of the analytical formula, the impact of each factor on the optimal incentive mechanism will be further discussed in the numerical simulation section.

6.4.4 Optimal payoffs of each party and social welfare

Proposition 6.2. In model C, under the optimal incentive mechanism:

(1) The central government's optimal benefit is $\pi_c^{**} = (1-\beta^{**})[n^{**} + \gamma\theta e_L^{**} + \gamma(1-\theta)e_H^{**}] - \beta^{**}m^{**} - \alpha^{**} + \frac{\lambda(\beta^{**}m^{**})^2}{2}$;

(2) The local government's optimal utility is $U_l^{**} = U_0 = 0$;

(3) The high-cost developer's optimal utility is $U_{dH}^{**} = U_0 = 0$; the low-cost developer's optimal utility is

$$U_{dL}^{**} = \frac{\dfrac{(h_H-h_L)h_L\gamma^2(1-\theta)^2\left(\gamma^2+h_H\rho_2\sigma_1^2\right)^2}{\left\{\begin{gathered} h_L^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1^2]+h_H^2[\gamma^2\theta+h_L(1-\theta)(\rho_1+\rho_2)\sigma_1^2] \\ [\gamma^4\theta\mu+h_L^2(\rho_1+\rho_2)\sigma_1^2+h_L\gamma^2(1+\theta\mu\rho_2\sigma_1^2)] \\ +h_Hh_L\gamma^2\begin{bmatrix}\gamma^4(1-2\theta)\theta\mu+h_L^2(\rho_1+\rho_2)\sigma_1^2\left(1-2\theta+(1-\theta)^2\mu\rho_2\sigma_1^2\right) \\ +h_L\gamma^2(1-2\theta-(\theta+\theta^2-1)\mu\rho_2\sigma_1^2)\end{bmatrix}\end{gathered}\right\}^2}}{\dfrac{2h_H[\gamma^2(h_L+h_H\theta-2h_L\theta)+h_Hh_L(1-\theta)(\rho_1+\rho_2)\sigma_1^2]^2}{\left\{\begin{gathered} h_L^2\gamma^4(1-\theta)^2\mu[\gamma^2+h_L(\rho_1+\rho_2)\sigma_1^2]+h_Hh_L\gamma^2(1-2\theta)[\gamma^4\theta\mu+h_L\gamma^2\left(1+\mu\rho_2(\sigma_1^2+\sigma_2^2)\right) \\ +h_L^2\sigma_1^2(\rho_1+\rho_2+\mu\rho_1\rho_2(\sigma_1^2+\sigma_2^2)-\mu\rho_2^2((1-\theta)\sigma_1^2+\sigma_2^2))] \\ +h_H^2[\gamma^6\theta^2\mu+h_L\gamma^4\theta(1+\mu(\rho_1-\theta\rho_1+2\rho_2-\theta\rho_2)\sigma_1^2+\mu\rho_2\sigma_2^2) \\ +h_L^3(1-\theta)(\rho_1+\rho_2)\sigma_1^4(\rho_1+\rho_2+\mu\rho_1\rho_2\sigma_1^2+\mu\rho_2(\rho_1+\rho_2)\sigma_2^2) \\ +h_L^2\gamma^2\sigma_1^2(\rho_1+\rho_2+\mu\rho_1\rho_2(\sigma_1^2+\sigma_2^2)+\mu\rho_2^2(2(1-\theta)\theta\sigma_1^2+\sigma_2^2))]\end{gathered}\right\}^2}};$$

(4) Considering that social welfare is the sum of the principal's and the agent's welfare (X. Yang et al., 2021), the social welfare is $W^{**} = \pi_c^{**} + U_l^{**} + U_{dH}^{**} + U_{dL}^{**}$.

Proof: By substituting the optimal results from Lemma 6.8 back into the optimal decisions of the local government and the developer, we can derive the optimal strategies for each party, thereby calculating the optimal benefit and utilities for each party.

Proposition 6.2 demonstrates that, under the collusion scenario, after implementing the optimal incentive mechanism, the central government, acting as the "pure principal", can still achieve strictly positive returns. On the other hand, the local government, acting as the "intermediary", and the high-cost developer, acting as the "pure agent", only obtain retained utility. The low-cost developer, however, receives additional utility beyond retained utility.

6.5 Comparative Analysis

By solving the incentive models for collusion and non-collusion scenarios, Sections 6.3 and 6.4 obtained the optimal decisions, corresponding returns and utilities for each party in the two situations. This section analyses and compares the decisions and utilities of each party in the two scenarios, leading to the following conclusions.

6.5.1 Governments' incentive strategies and returns

Conclusion 6.1. In two different models, for the central government: (1) $\alpha^* > \alpha^{**}$; (2) $\beta^* = \beta^{**}$; (3) ${\pi_c}^* = {\pi_c}^{**}$.

Proof: $\alpha^* - \alpha^{**} = \frac{1}{2\lambda}$, $\beta^* - \beta^{**} = 0$ and ${\pi_c}^* - {\pi_c}^{**} = 0$.

The central government, considering the collusion behaviour between the local government and developer, reduces the fixed payments to the local government but does not change the incentive intensity. Under the optimal incentive mechanism design, collusion behaviour does not harm the central government's returns, and its returns remain equal in both scenarios. Due to collusion behaviour, the central government ends up shouldering the cost for "illusory" environmental benefits, leading to unnecessary expenses. In this situation, the optimal strategy for the central government is to restrict the fixed payments to the local government without altering the incentive intensity. This approach ensures that the local government and developer do not decrease their green efforts, thereby reaping the environmental benefits associated with those efforts and achieving the goal of high-quality GB development. It also safeguards the central government's returns from being harmed by collusion behaviour.

Corollary 6.2. $\frac{\partial(\alpha^*-\alpha^{**})}{\partial\lambda} < 0$.

Proof: $\frac{\partial(\alpha^*-\alpha^{**})}{\partial\lambda} = -\frac{1}{2\lambda^2} < 0$.

As shown in Corollary 6.2, the central government's reduced fixed payments due to collusion behaviour exhibit a negative correlation with the penalty coefficient. In other words, as the penalty coefficient for collusion behaviour increases in model C, the central government increases its fixed payments to the local government. This is because higher penalties discourage collusion tendencies between the local government and developer. Therefore, the central government is willing to provide more fixed payments as incentives to encourage and ensure the participation of the local government.

Conclusion 6.2. In two different models, for the local government: (1) $a_L^* = a_L^{**}$, $a_H^* = a_H^{**}$; (2) $b_L^* = b_L^{**}$, $b_H^* = b_H^{**}$; (3) $n^* = n^{**}$; (4) $U_l^* = U_l^{**}$.

In the context of collusion, the local government's green efforts and incentive contracts with developers remain unaffected compared with the non-collusion scenario. This implies that collusion behaviour has no influence on the local government's decision-making. Although the local government may gain additional returns through overreporting environmental benefits during collusion, the top-level design of the central government ensures that the local government does not derive extra utility from collusion behaviour. This highlights the effectiveness of the central government's policy incentive mechanism in safeguarding high-quality GB development and maintaining policy effectiveness, thereby mitigating the negative impacts of collusion on the central government and the environment.

6.5.2 Developer's response strategy and utility

Conclusion 6.3. In two different models, for the high-cost developer: (1) ${e_H}^* = {e_H}^{**}$; (2) ${U_{dH}}^* = {U_{dH}}^{**}$; for the low-cost developer: (1) ${e_L}^* = {e_L}^{**}$; (2) ${U_{dL}}^* = {U_{dL}}^{**}$.

Developers with private cost information make decisions that are unaffected by collusion behaviour. Regardless of whether collusion occurs, these developers will maximise their green efforts, and the level of effort will remain the same. Similarly, under the top-level design of the central government, developers cannot derive additional utility from collusion behaviour.

6.5.3 Greenness, environmental benefits and social welfare

Conclusion 6.4. In two different models: (1) ${g_L}^* = {g_L}^{**}$, ${g_H}^* = {g_H}^{**}$; (2) ${\pi_e}^* = {\pi_e}^{**}$; (3) $W^* = W^{**}$.

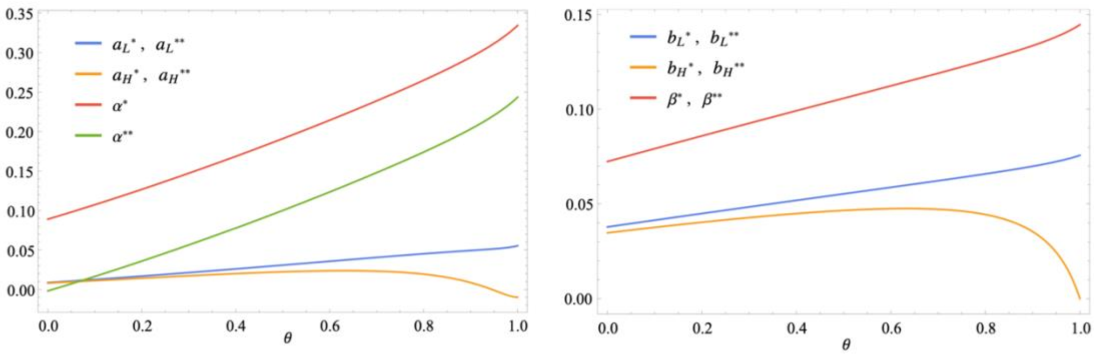
Local government–developer collusion does not diminish GB greenness, environmental benefits and overall social welfare. Regardless of collusion, GB greenness, environmental benefits and social welfare remain unchanged. This is because, under the central government's top-level design, the local government and developer exert the same level of green efforts as they would without collusion, thereby maintaining consistent GB greenness and generating equivalent environmental benefits.

The comparative analysis above indicates that the central government can effectively counteract the negative effects of local government–developer collusion by implementing an optimal incentive mechanism. This mechanism maintains the existing incentive intensity while limiting fixed payments to local government, considering collusion behaviour. Under this top-level design, collusion does not impact the interests of the parties involved. Additionally, both the local government and developer maintain their level of green efforts, ensuring that GB greenness, environmental benefits and overall social welfare remain unchanged. This approach promotes the advancement of high-quality GB development in China.

6.6 Numerical Analysis and Discussion

Given the complexity of optimal decision-making and utility functions for all parties involved, this section employs numerical analysis to visually demonstrate the impact of different parameter values on optimal strategies and utilities. This approach aims to gain further managerial insights. Due to the lack of first-hand data, this section refers to previous studies (W. Chen & Li, 2021; C. Zhao et al., 2022) and incorporates expert interviews. The initial parameter values are set as follows: $h_H = 4$, $h_L = 2$, $\gamma = 5$, $\mu = 5$, ${\sigma_1}^2 = {\sigma_2}^2 = 9$, $\rho_1 = 4$, $\rho_2 = 3$, $p_H = 0.01$, $p_L = 0.012$.

6.6.1 Impact of low-cost developer market share (θ)

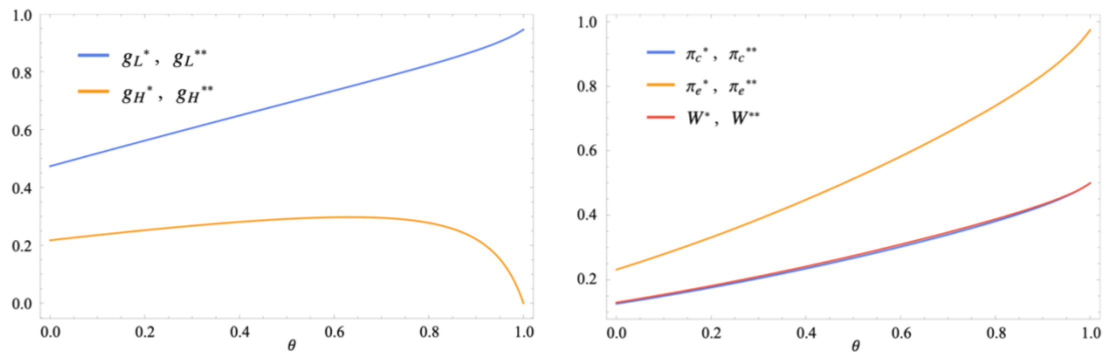


(a) (b)

Figure 6.2 (a) Impact of θ on fixed payment; (b) Impact of θ on incentive intensity.

Figure 6.2 depicts the impact of θ on the optimal contracts of the central and local governments. In the collusion scenario, the central government consistently provides lower fixed payments compared with the non-collusion scenario, while maintaining the same incentive intensity. This verifies Conclusion 6.1. Furthermore, the local government offers higher fixed payments and incentive intensity to the low-cost developer to incentivise green efforts and promote GB.

Regarding the impact of θ on the optimal contracts, as the market share of low-cost developers increases, the central government provides higher fixed payments and incentive intensity to the local government. A similar trend is observed in the local government's contract with the low-cost developer. However, the relationship between the local government's contract with a high-cost developer and θ follows an inverted "U" shape. Initially, the local government increases fixed payments and incentive intensity for the high-cost developer as θ increases. However, when θ exceeds a certain threshold, the local government lowers the fixed payments and incentive intensity for the high-cost developer. This is because a higher value of θ implies a higher probability of the developer being low-cost, increasing the likelihood of the developer falsifying its cost information to appear as a high-cost developer, thereby exacerbating information uncertainty. The government takes this into consideration and intensifies incentives to encourage developers to provide truthful information. However, when the market share of low-cost developers is sufficiently high, the government, considering its own interests, cannot continuously increase incentives. Therefore, the government chooses to limit rewards for the high-cost developer to weaken the motivation for the low-cost developer to falsify its information.



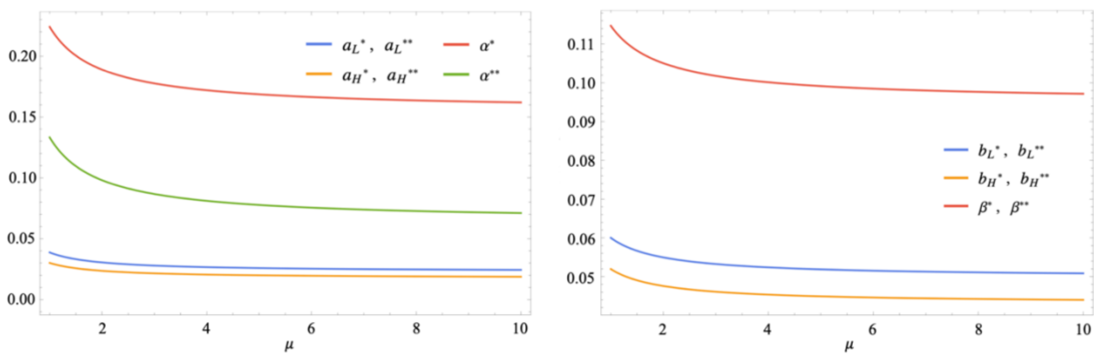
(a) (b)

Figure 6.3 (a) Impact of θ on GB greenness; (b) Impact of θ on central government benefit, environmental benefits and social welfare.

Figure 6.3(a) reveals that the greenness of GBs constructed by the low-cost developer increases with θ, reflecting its higher level of green efforts. In contrast, the greenness of GBs constructed by the high-cost developer exhibits an inverted "U" relationship with θ. Figure 6.3(b) demonstrates that the concerted efforts of the local government and developer result in amplified central government revenue, environmental benefits and social welfare. Increasing the market share of low-cost developers proves advantageous because it leads to higher central government revenue, facilitates environmental preservation and enhances societal well-being. In other words, augmenting the market share of low-cost developers not only improves central government benefits but also contributes to environmental conservation and overall social welfare.

6.6.2 Impacts of cost coefficient of green efforts for the local government (μ)

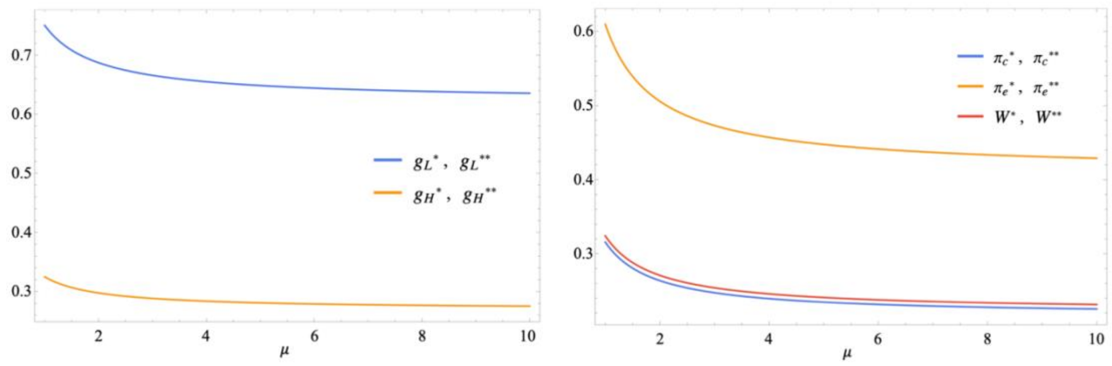
Based on the parameter values set in the previous context, to examine the impacts of the local government's green effort cost coefficient, this subsection considers μ as the independent variable, assuming $\theta = 0.4$. A higher value of μ indicates a higher cost borne by the local government per unit of green effort.



(a) (b)

Figure 6.4 (a) Impact of μ on fixed payment; (b) Impact of μ on incentive intensity.

Figure 6.4 shows that as the local government's effort cost coefficient increases, both the central and local governments decrease their fixed payments and incentive intensity. This suggests that, when dealing with financially constrained local governments, the central government should formulate optimal incentive contracts based on their costs rather than unilaterally increasing rewards. As the central government reduces incentive intensity and fixed payments, the local government also decreases incentives for developers accordingly. Additionally, as μ increases, the declining trends of fixed payments and incentive intensity gradually plateau.



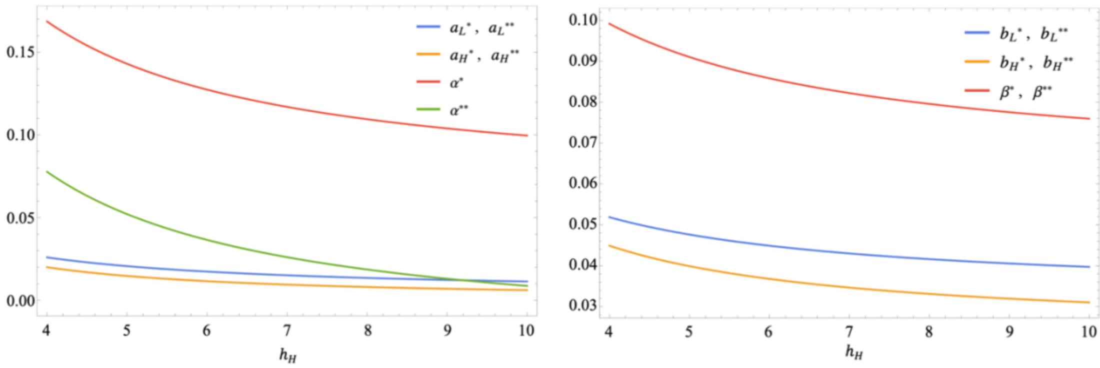
(a) (b)

Figure 6.5 (a) Impact of μ on GB greenness; (b) Impact of μ on central government benefit, environmental benefits and social welfare.

Figure 6.5(a) demonstrates a decline in the greenness of GBs across different cost levels for developers, as it is closely associated with their green efforts. Under the combined influence of the local government and developer, Figure 6.5(b) reveals a decrease in the central government's benefits, environmental benefits and social welfare, notably affecting environmental benefits. Thus, the high unit cost of effort for the local government has adverse implications for both environmental protection and the enhancement of overall social welfare. Furthermore, it diminishes the central government’s revenue.

6.6.3 Impacts of cost coefficient of green efforts for the high-cost developer ($\mathbf{h}_H$)

Similarly, this subsection considers h_H as the independent variable to analyse the impacts of the high-cost developer’s green effort cost coefficient.

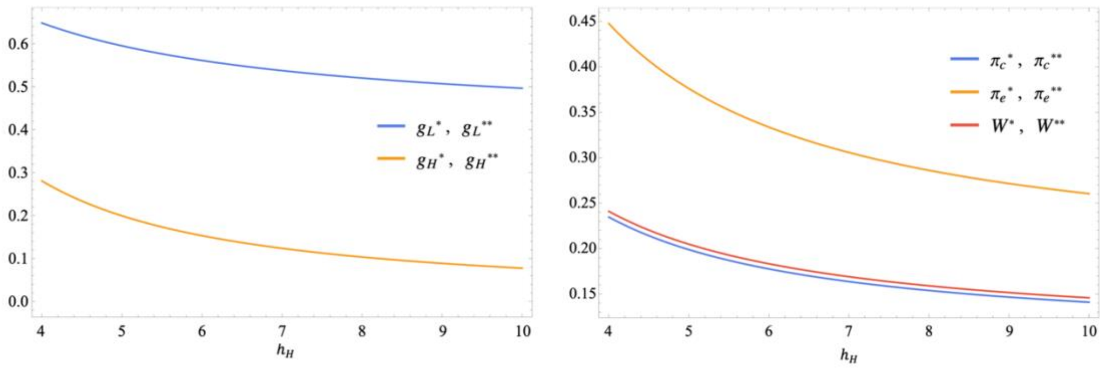


(a) (b)

Figure 6.6 (a) Impact of h_H on fixed payment; (b) Impact of h_H on incentive intensity.

Generally, as h_H increases, both the optimal incentive intensity and fixed payments for the two levels of government decrease. The impact of h_H on the optimal contract is more significant for the central government. Regarding the local government, as h_H increases, it tends to reduce the incentive intensity for the high-cost developer. Interestingly, even though the unit cost of effort for low-cost developer remains unchanged, the local government still decreases their incentive intensity and fixed payment. This is because the increase in costs for high-cost developer, leading to a decrease in their green efforts, prompts the central government to reduce overall incentives to the local government. Consequently, the local government further reduces incentives for the low-cost developer.

From Figure 6.7, similar to the impact of the local government's effort cost coefficient, the greenness of GBs decreases for different cost developers as h_H increases, with a more pronounced decline for the high-cost developer. Under the combined influence of the local government and developer, the central government experiences decreases in revenue, environmental benefits, and social welfare, with a notable decline in environmental benefits. Therefore, the high unit cost of effort for developers has adverse implications for both environmental protection and the enhancement of social welfare. Additionally, it diminishes the central government's revenue.

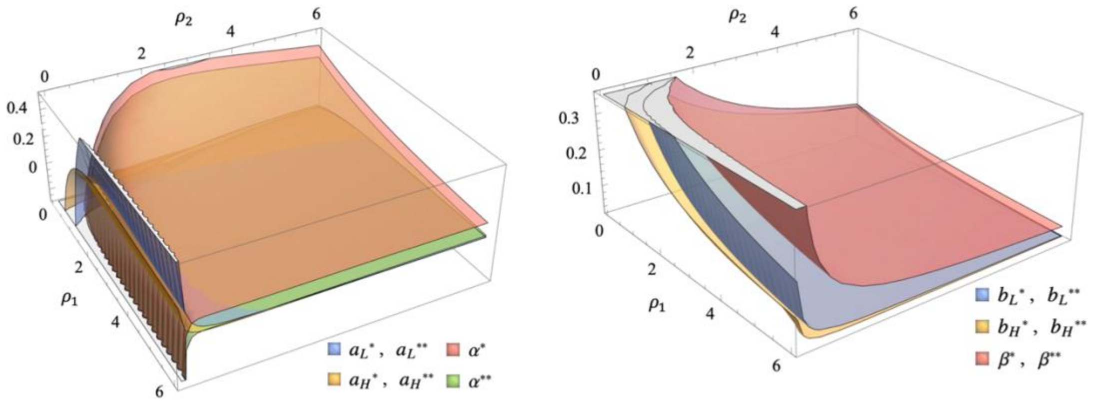


(a) (b)

Figure 6.7 (a) Impact of h_H on GB greenness; (b) Impact of h_H on central government benefit, environmental benefits and social welfare.

6.6.4 Impacts of risk aversion coefficient (ρ_1 and ρ_2)

To investigate the impacts of risk aversion levels of the local government and developer, this subsection considers ρ_1 and ρ_2 as independent variables.



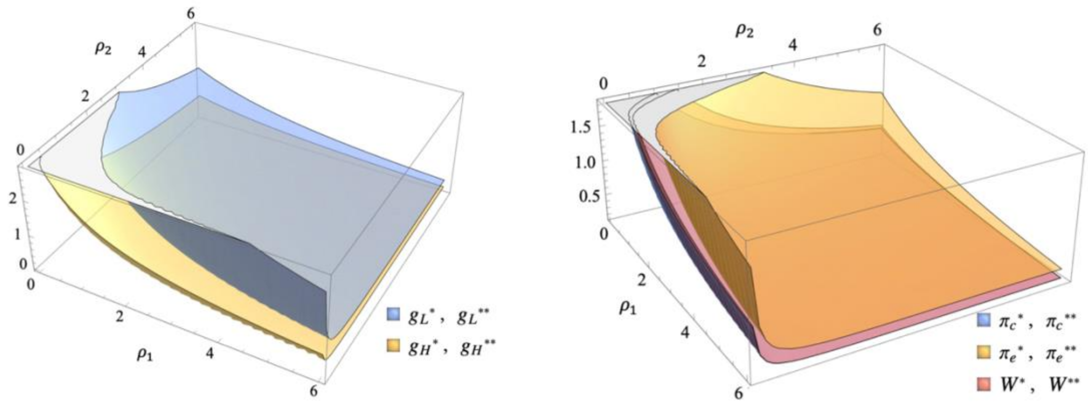
(a) (b)

Figure 6.8 (a) Impact of ρ_1 and ρ_2 on fixed payment; (b) Impact of ρ_1 and ρ_2 on incentive intensity.

Figure 6.8(a) illustrates the changes in fixed payments for the two levels of government. Overall, when both the local government and developer exhibit higher levels of risk aversion, the central government reduces its fixed payment to the local government. Conversely, when risk aversion is lower, the local government increases its fixed payment to the developer. The local government, as the implementer of central policies, bears the responsibility of promoting the high-quality development of GBs. To ensure developer participation in GB initiatives, the local government provides higher fixed payments to compensate for the risk costs associated with risk-averse developer. On the other hand, for the central government, higher risk aversion indicates a relatively conservative attitude from the developer and local government in fulfilling GB development tasks. To avoid losses, the central government reduces payments to the local government.

Figure 6.8(b) reveals that incentive intensity declines as risk aversion levels increase for both levels of government. Generally, the incentive intensity weakens as risk aversion increases. The lowest incentive intensity occurs when both the local government and the developer exhibit the highest risk aversion. Higher incentive intensity implies that agents bear higher risk costs.

Thus, when agents exhibit higher levels of risk aversion, the principal chooses to reduce the incentive intensity to mitigate the agents' risk costs. Furthermore, the impact of risk aversion on the local government's incentive intensity is more significant than on the central government's. As risk aversion increases, the local government's incentive intensity decreases faster compared with the central government's. The local government also reduces the incentive disparity between high- and low-cost developers. When considering the risk aversion levels of both the local government and developer, the overall incentive intensity is lower compared with considering only one party's risk aversion. The risk aversion level of the local government has a more pronounced effect on the incentive intensity of both levels of government, with a sharp decrease as its risk aversion intensifies. In contrast, the developer's risk aversion impact is relatively moderate.



(a) (b)

Figure 6.9 (a) Impact of ρ_1 and ρ_2 on GB greenness; (b) Impact of ρ_1 and ρ_2 on central government benefit, environmental benefits and social welfare.

From Figure 6.9, the risk aversion levels of the developer and local government have adverse effects on the promotion of GBs. As risk aversion intensifies, the GB greenness decreases, and the central government's benefit, environmental benefits and social welfare are reduced.

Further comparative analysis reveals that the risk aversion level of the local government has a more significant impact on GB greenness, the central government's benefit, environmental benefits and social welfare. As the risk aversion of the local government increases, there is a sharp decline in GB greenness, the central government's benefit, environmental benefits and social welfare. This underscores the crucial role of the local government in facilitating the high-quality development of GBs.

6.6.5 Comparison with previous research

Previous designs of incentive mechanisms for promoting GBs have overlooked the impact of information asymmetry between central and local governments, focusing solely on optimal policy incentive mechanisms under information asymmetry between governments and enterprises. Specifically, the policy incentive mechanisms designed by W. Chen & Li (2021), W. Chen & Hong (2015) and Cai D. et al. (2023) concentrate on addressing the information advantage held by enterprises but fail to provide policy guidance for the central government to mitigate the opportunistic behaviour that local governments might exhibit due to their information advantage.

This chapter's key contribution lies in proposing policy incentive mechanisms from a MLG perspective, thus addressing the adverse effects of information asymmetry between hierarchical levels on the promotion of GBs. The findings reveal a positive correlation between developers' green efforts and the local government's incentive intensity (see Corollaries 6.1.1 and 6.5.1). Similar results were found by W. He et al. (2022), who noted that government subsidies could enhance developers' efforts. However, this study further uncovers the relationship between central and local incentive intensities (see Corollaries 6.3.2 and 6.7.2), indicating that the central government's incentive intensity directly influences that of the local government, which in turn affects the developers' green efforts and the quality of GBs. Additionally, this study finds that the local government needs to pay additional information rent to the low-cost developer to achieve information disclosure, similar to the findings of W. Chen & Hong (2015). However, this study further demonstrates that the central government can reduce information costs through incentive mechanism design and eliminate the adverse effects of collusion. Moreover, this chapter deepens the understanding of the impacts of cost coefficients, the market share of low-cost developers and risk aversion levels on the optimal government incentive mechanisms.

6.7 Chapter Summary

In China's MLG system, information asymmetry between levels hinders the promotion of GBs. Specifically, such asymmetry can lead to developers disguising their cost information, causing adverse selection, or to local governments and developers reducing their green efforts, resulting in moral hazard. This chapter investigates the design of policy incentive mechanisms for promoting high-quality GBs by central and local governments under information asymmetry, uncovering hidden information and incentivising the local government and developer to enhance their green efforts. A dual principal-agent model comprising the central government, local government and developer is constructed. Optimal incentive mechanisms for the governments are derived under both non-collusion and collusion scenarios, along with the agents' green effort strategies. The analysis yields the following conclusions:

1. The central government can effectively mitigate the negative impacts of collusion and information asymmetry through optimal incentive mechanism design. Despite collusion, the optimal incentive intensity remains unchanged while fixed payments decrease. It ensures unchanged GB quality, central government revenue, environmental benefits and social welfare while avoiding additional fiscal burden.
2. The local government can achieve information screening and incentivise developers to maximise their green efforts through optimal incentive mechanism design. For the low-cost developer, higher incentive intensity and fixed payments are provided to encourage

information disclosure, as there is an incentive to conceal true information. By contrast, the incentive intensity and fixed payments for the high-cost developer are restricted to ensure reservation utility.

3. The central government's optimal incentive intensity and fixed payments are positively correlated with the market share of low-cost developers and negatively correlated with the green effort cost coefficients. As risk aversion levels increase, the optimal incentive intensity decreases monotonically, while the relationship with optimal fixed payments is non-monotonic.
4. The local government's optimal incentive intensity is positively correlated with the central government's but consistently lower. It is negatively correlated with green effort cost coefficients. With the increasing market share of low-cost developers, the local government provides higher incentive intensity and fixed payments to the low-cost developer, while the incentive intensity for the high-cost developer exhibits an initially increasing trend followed by a decrease. Risk aversion levels have a monotonically decreasing impact on incentive intensity and a non-monotonic effect on fixed payments.
5. The developer's green efforts are influenced by the incentive intensity provided by the government. Higher incentive intensity prompts high- and low-cost developers to enhance the quality of GBs. Additionally, the low-cost developer consistently exhibits higher green efforts compared with the high-cost developer.

CHAPTER 7 Empirical Examination of Policy Incentive Mechanisms for GB Promotion

7.1 Introduction

Chapters 5 and 6 explore the dynamic behaviours and the optimal policy incentive mechanisms within a MLG structure, primarily through mathematical analysis. The stability and reliability of these conclusions require further empirical validation. Hence, this chapter formulates research hypotheses based on the aforementioned mathematical analysis, collects relevant data through surveys and employs both qualitative and quantitative methods to test these hypotheses, thereby validating the previous models.

7.2 Research Methods and Hypotheses

This chapter utilises a survey methodology for empirical analysis. Firstly, measurement scales are constructed based on existing literature and prior analysis. Subsequently, surveys are conducted among experts in the GB industry. This method, which incurs relatively low costs while yielding high-quality data (KELLEY et al., 2003), is widely used in construction management research (Annunziata et al., 2016; B. Huang et al., 2016; X. Qin et al., 2016). Finally, various statistical methods are employed to process and analyse the data to test the research hypotheses.

In the preceding mathematical analysis, several key conclusions were drawn. First, it was found that the central government's initial implementation of strict supervision facilitates the proactive promotion of GBs by more local governments and developers. Furthermore, central government penalties for collusion are conducive to encouraging more local governments and developers to actively promote GBs. The study also found that high rewards and penalties for local governments facing high implementation costs encourage more local governments to promote GBs. Conversely, high rewards and penalties for local governments with low implementation costs discourage more developers from promoting GBs. From the perspective of local governments, it was observed that incentivising developers rather than consumers is more effective in encouraging more developers to promote GBs. Additionally, local governments penalising developers is more effective than the central government penalising collusion in encouraging more developers to promote GBs. Consumers' willingness to pay for GBs also encourages more developers to promote GBs. Reducing fixed payments to local governments during instances of collusion while maintaining incentive intensity enhances the local government's enthusiasm to promote GBs. Furthermore, the central government's provision of higher incentive intensity to local governments with low execution costs stimulates their enthusiasm to promote GBs. Providing higher incentive intensity to low-cost developers positively influences their efforts to improve GB quality. Similarly, increasing the market share of low-cost developers also encourages greater efforts to enhance GB quality. Based on these findings, the following research hypotheses are proposed:

H1: Incentive mechanisms linked to environmental benefits positively influence local governments' efforts to promote GBs.

H2: Incentive mechanisms tied to the degree of building greenness positively influence developers' efforts to enhance the quality of GBs.

H3: Reducing fixed payments to local governments during collusion while maintaining incentive intensity positively influences local governments' efforts to promote GBs.

H4: Providing higher incentive intensity to local governments with low implementation costs positively influences local governments' efforts to promote GBs.

H5: Offering higher incentive intensity to low-cost developers by local governments positively influences developers' efforts to improve the quality of GBs.

H6: Increasing incentive intensity by the government positively influences developers' efforts to improve the quality of GBs.

H7: The central government's initial implementation of strict supervision is positively correlated with the participation of local governments and developers in promoting GBs.

H8: Central government penalties for collusion are positively correlated with the participation of local governments and developers in promoting GBs.

H9: High rewards and penalties for local governments facing high implementation costs by the central government are positively correlated with the participation of local governments in promoting GBs.

H10: High rewards and penalties for local governments with low implementation costs by the central government are negatively correlated with developers' participation in promoting GBs.

H11: Rewards for developers by local governments are more effective than rewards for consumers in encouraging more developers to promote GBs.

> H11(a): Rewards from local governments to developers are positively correlated with developers' participation in promoting GBs.
>
> H11(b): Rewards from local governments to consumers are positively correlated with developers' participation in promoting GBs.

H12: Penalties for developers by local governments are more effective than central government penalties for collusion in encouraging more developers to promote GBs.

> H12(a): Penalties from local governments to developers are positively correlated with developers' participation in promoting GBs.
>
> H12(b): Central government penalties for collusion are positively correlated with developers' participation in promoting GBs.

H13: Consumers' willingness to pay for GBs is positively correlated with developers' participation in promoting GBs.

H14: The market share of low-cost developers is positively correlated with developers' efforts to enhance the quality of GBs.

7.3 Selection of Research Subjects and Data Collection

7.3.1 Design of research scales

The design of the research scales includes the structure of the questionnaire and the measurement of observed variables. The structure of the questionnaire involves determining the content, scope and respondents for information collection. The measurement of observed variables involves defining the questionnaire options and scoring methods. Based on the reviews and conclusions from previous chapters, an initial draft was developed. Subsequently, the research group discussed the content, wording and format of the items, sought opinions from experts in GB fields and revised the measurement items to form a second draft. Based on this, a pre-fill survey was conducted to refine the expression and accuracy of the measurement items, resulting in the final version, as shown in Table 7.1. The specific content of the questionnaire is provided in Appendix B. Experts in the GB industry were selected as subjects for this research. The questionnaire was designed with a targeted approach and distributed both online and offline. The online distribution was mainly done through the "Wenjuanxing" platform for online questionnaire preparation and distribution, while offline distribution was primarily conducted through interviews, during which respondents filled out the questionnaire.

Table 7.1 Variable definitions.

Variables	Definitions	Observed variables	Measurement item content

z1	Central government's initial strict supervision	X12	The central government should initiate early inspections on GBs
		X13	The central government should take the lead in special inspections and maintain high inspection frequency
		X14	The central government should establish an evaluation and assessment system for GB objectives
z2	Local government's participation in promoting GBs	X18	The local government makes significant contributions to promoting GBs
		X19	The local government implements strict regulations on GBs
		X20	The local government has issued clear policies to support GB promotion
z3	Developers' participation in promoting GBs	X21	The proportion of GB projects in developers' construction projects is high
		X22	Developers are willing to invest more costs in developing GBs
		X23	Developers do not engage in fraudulent certification of green projects

z4	Central government's penalty for collusion	X15	The central government should fine developers for bribery
		X16	The central government should pursue legal responsibility for developers' bribery
		X17	The central government should hold local government officials accountable for misconduct
z5	Local government's implementation costs	X24	The cost of formulating GBPs by the local government is high
		X25	The risk of implementing GBPs by the local government is high
		X26	The coordination cost of implementing GBPs by the local government is high
z6	Central government's rewards and penalties to local governments	X27	The central government should provide significant transfer payments to support local GBPs
		X28	The performance assessment of local governments by the central government should heavily weigh the completion of GB objectives

		X29	The central government should hold local governments accountable for not promoting GBs aggressively
		X30	The central government should promptly report and rectify local governments that fail to meet targets
z7	Local government rewards to developers	X31	Local governments provide subsidies to developers for GBs
		X32	Local governments give priority awards to GBs
		X33	GB developers receive credit support
		X34	Local governments provide floor area ratio incentives to GB developers
z8	Local government rewards to consumers	X35	Increased housing provident fund loan amounts for purchasing GBs
		X36	There are preferential loan interest rates for purchasing GBs
		X37	Local governments provide subsidies to buyers of GBs

z9	Local government penalties to developers	X38	Local governments fine developers for GB violations
		X39	Local governments downgrade or revoke the qualifications of developers who violate GB regulations
		X40	Local governments record the integrity of developers who violate GB regulations
z10	Consumers' willingness to pay for GBs	X41	Consumers support the development of GB
		X42	Consumers are keen on purchasing GBs
		X43	Consumers are willing to live in GBs
z11	Market share of low-cost developers	X44	The development cost of GB developers in the market is generally low
		X45	Low-cost GB developers are common in the market
		X46	High-cost GB developers are rare in the market
z12	Developers' efforts in promoting GBs	X47	Developers adopt more advanced green technologies and management measures

	X48	Developers choose more environmentally friendly building materials
	X49	Developers are willing to invest more to improve the quality of GBs

7.3.2 Descriptive statistics of data

The questionnaire survey was conducted in April 2023. Researchers distributed the questionnaires both online and offline, resulting in a total of 300 distributed questionnaires. After screening, 237 valid questionnaires were retained (the effective sample recovery rate was 79%). Subsequently, the data were analysed using Stata software. The demographic characteristics of the respondents were measured using a coding measurement method, focusing on gender, age, occupation, education level and work experience. In this study, these variables were treated as control variables and not discussed in detail, as the main focus is to test the research hypotheses presented earlier.

Table 7.2 Statistical characteristics of valid samples.

Statistical Item	Content Classification	Number of Samples	Percentage
Gender	Male	167	70.46%
	Female	70	29.54%
Age	30–40	34	14.35%
	40–50	141	59.49%

	50–60	46	19.41%
	Over 60	16	6.75%
Occupation	Researchers	115	48.52%
	Government and Institutions	69	29.11%
	Others	53	22.36%
Education Level	Bachelor's	58	24.47%
	Master's	88	37.13%
	Doctoral	91	38.40%
Work Experience in GB	3–5 years	0	0
	6–10 years	50	21.10%
	More than 10 years	187	78.90%

Note: Sample size N = 237

The descriptive statistics of the sample test data for the measurement items of each variable are shown in Table 7.3, including the minimum, maximum, mean and standard deviation of all measurement items in the questionnaire.

Table 7.3 Descriptive statistics of measurement items for variables.

Variable	Observed value	Mean	Standard deviation	Minimum value	Maximum value
X6	237	4.143	0.698	3	5
X7	237	4.004	0.946	2	5
X8	237	3.819	0.811	2	5
X9	237	3.903	0.750	2	5
X10	237	3.945	0.814	2	5
X11	237	4.232	0.639	3	5
X12	237	3.405	1.130	2	5
X13	237	3.139	1.208	1	5
X14	237	3.308	1.250	1	5
X15	237	3.270	1.202	1	5
X16	237	3.076	1.290	1	5
X17	237	3.388	1.253	1	5
X18	237	3.287	1.030	1	5
X19	237	2.962	1.162	1	5
X20	237	3.093	1.127	1	5

X21	237	2.932	1.177	1	5
X22	237	2.692	1.201	1	5
X23	237	3.051	0.994	1	5
X24	237	3.190	0.953	1	5
X25	237	3.262	1.171	1	5
X26	237	3.481	1.301	1	5
X27	237	3.401	1.051	1	5
X28	237	3.422	1.061	1	5
X29	237	3.300	1.203	2	5
X30	237	3.574	1.204	1	5
X31	237	3.380	1.207	1	5
X32	237	3.544	1.071	2	5
X33	237	3.422	1.420	1	5
X34	237	3.194	1.383	1	5
X35	237	3.207	1.497	1	5
X36	237	3.173	1.353	1	5
X37	237	3.304	1.289	1	5

X38	237	3.114	1.252	1	5
X39	237	3.021	1.300	1	5
X40	237	3.270	1.547	1	5
X41	237	3.165	1.290	1	5
X42	237	2.747	1.191	1	5
X43	237	3.245	1.242	1	5
X44	237	3.072	1.255	1	5
X45	237	3.055	1.026	1	5
X46	237	3.139	1.246	1	5
X47	237	3.186	1.116	1	5
X48	237	3.371	1.015	1	5
X49	237	3.266	1.263	1	5

7.3.3 Reliability and validity analysis

The data were first assessed for credibility and reliability using Cronbach's alpha coefficient (α) as the metric (Nunnally, 1994). The α value, ranging from 0 to 1, indicates the internal consistency of the data, with higher values reflecting stronger reliability. Generally, an α value exceeding 0.7 is deemed acceptable (George & Mallery, 2003). In this study, the results show that all Cronbach's alpha coefficient values are greater than 0.7, indicating the reliability of the data for subsequent analyses. The validity was assessed using exploratory factor analysis (EFA).

Prior to the empirical research, the sample was subjected to the KMO (Kaiser-Meyer-Olkin) test and Bartlett's test of sphericity. As shown in Table 7.4, the KMO value is 0.887, exceeding the threshold of 0.6, indicating good validity.

Table 7.4 KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.887	
Bartlett's Test of Sphericity	Approx. Chi-Square	2174.362
	df	236
	Sig.	0.000

The validity test results for the measurement scales of the central government's strict supervision and penalty of collusion are shown in Table 7.5. As shown, all communalities in the measurement questionnaire are greater than 0.5, and all factor loadings are greater than 0.6, indicating that this part of the scale effectively extracts the required information. The KMO values for these scales are 0.889 and 0.701, respectively, both greater than 0.6, indicating good validity. The cumulative variance explained rates are 77.3% and 81.2%, both greater than 50%, indicating that the research items' information can be effectively extracted. Therefore, the measurement scales for these variables remain unchanged.

Table 7.5 Validity test for central government's initial strict supervision and penalty for collusion.

Central government's initial strict supervision			Central government's penalty for collusion		
Item	Factor loading	Communality	Item	Factor loading	Communality
X12	0.834	0.711	X15	0.931	0.876
X13	0.672	0.611	X16	0.763	0.712
X14	0.622	0.533	X17	0.822	0.744
Eigenvalue	1.994	-	Eigenvalue	2.382	-
Cumulative	0.773	-	Cumulative	0.812	-
KMO	0.889	-	KMO	0.701	-
p-value	0.000	-	*p*-value	0.000	-

The validity test results for the measurement scales of local governments' and developers' participation in promoting GBs are shown in Table 7.6. As shown, all communalities in the measurement questionnaire are greater than 0.5, and all factor loadings are greater than 0.6, indicating that this part of the scale effectively extracts the required information. The KMO values for these scales are 0.873 and 0.781, respectively, both greater than 0.6, indicating good validity. The cumulative variance explained rates are 71.3% and 89.1%, both greater than 50%, indicating that the research items' information can be effectively extracted. Therefore, the measurement scales for these variables remain unchanged.

Table 7.6 Validity test for local government and developer participation in promoting GBs.

Local government's participation in promoting GBs			Developers' participation in promoting GBs		
Item	Factor loading	Communality	Item	Factor loading	Communality
X18	0.811	0.702	X21	0.821	0.801
X19	0.732	0.671	X22	0.723	0.719
X20	0.682	0.514	X23	0.898	0.732
Eigenvalue	2.091		Eigenvalue	2.308	
Cumulative	0.713		Cumulative	0.891	
KMO	0.873		KMO	0.781	
p-value	0.000		*p*-value	0.000	

The validity test results for the measurement scales of local government enforcement costs and the central government's rewards and penalties to local governments are shown in Table 7.7. As shown, all communalities in the measurement questionnaire are greater than 0.5, and all factor loadings are greater than 0.6, indicating that this part of the scale effectively extracts the required information. The KMO values for these scales are 0.811 and 0.821, respectively, both greater than 0.6, indicating good validity. The cumulative variance explained rates are 75.2% and 63.1%, both greater than 50%, indicating that the research items' information can be effectively extracted. Therefore, the measurement scales for these variables remain unchanged.

Table 7.7 Validity test for local government implementation costs and central government rewards and penalties.

Local government implementation costs			Central government's rewards and penalties to local governments		
Item	Factor loading	Communality	Item	Factor loading	Communality
X24	0.891	0.702	X27	0.843	0.718
X25	0.819	0.671	X28	0.799	0.719
X26	0.721	0.514	X29	0.818	0.743
			X30	0.799	0.701
Eigenvalue	2.297		Eigenvalue	2.326	
Cumulative	0.752		Cumulative	0.631	
KMO	0.811		KMO	0.821	
p-value	0.000		*p*-value	0.000	

The validity test results for the measurement scales of local rewards to developers and consumers are shown in Table 7.8. As shown, all communalities in the measurement questionnaire are greater than 0.5, and all factor loadings are greater than 0.6, indicating that this part of the scale effectively extracts the required information. The KMO values for these scales are 0.865 and 0.835, respectively, both greater than 0.6, indicating good validity. The cumulative variance explained rates are 75.4% and 61.8%, both greater than 50%, indicating that the research items' information can be effectively extracted. Therefore, the measurement scales for these variables remain unchanged.

Table 7.8 Validity test for local rewards to developers and consumers.

Local government incentives to developers			Local government incentives to consumers		
Item	Factor loading	Communality	Item	Factor loading	Communality
X31	0.819	0.754	X35	0.853	0.775
X32	0.854	0.718	X36	0.765	0.775
X33	0.765	0.653	X37	0.865	0.721
X34	0.713	0.712			
Eigenvalue	2.304		Eigenvalue	2.349	
Cumulative	0.754		Cumulative	0.618	
KMO	0.865		KMO	0.835	
p-value	0.000		*p*-value	0.000	

The validity test results for the measurement scales of local penalties to developers and consumers' willingness to pay for GBs are shown in Table 7.9. As shown, all communalities in the measurement questionnaire are greater than 0.5, and all factor loadings are greater than 0.6, indicating that this part of the scale effectively extracts the required information. The KMO values for these scales are 0.863 and 0.865, respectively, both greater than 0.6, indicating good validity. The cumulative variance explained rates are 63.3% and 63.3%, both greater than 50%, indicating that the research items' information can be effectively extracted. Therefore, the measurement scales for these variables remain unchanged.

Table 7.9 Validity test for local penalties to developers and consumers' willingness to pay for GBs.

Local government penalties to developers			Consumers' willingness to pay for GBs		
Item	Factor loading	Communality	Item	Factor loading	Communality
X38	0.819	0.765	X41	0.645	0.566
X39	0.728	0.647	X42	0.754	0.719
X40	0.654	0.522	X43	0.763	0.653
Eigenvalue	2.067		Eigenvalue	2.028	
Cumulative	0.633		Cumulative	0.633	
KMO	0.863		KMO	0.865	
p-value	0.000		*p*-value	0.000	

The validity test results for the measurement scales of low-cost developers' market share and developers' efforts in promoting GBs are shown in Table 7.10. As indicated, all communalities in the measurement questionnaire exceed 0.5, and all factor loadings exceed 0.6, demonstrating that this part of the scale effectively extracts the necessary information. The KMO values for the market share of low-cost developers and developers' efforts in promoting GBs are 0.815 and 0.912, respectively, both exceeding 0.6, indicating good validity. The cumulative variance explained rates for the scales are 64.4% and 62.2%, both exceeding 50%, indicating that the research items' information can be effectively extracted. Therefore, the measurement scales for these variables remain unchanged.

Table 7.10 Validity test for low-cost developers' market share and developers' efforts in promoting GBs.

Market share of low-cost developers			Developers' efforts in promoting GBs		
Item	Factor loading	Communality	Item	Factor loading	Communality
X44	0.854	0.765	X47	0.611	0.601
X45	0.811	0.665	X48	0.633	0.599
X46	0.745	0.731	X49	0.644	0.611
Eigenvalue	2.276		Eigenvalue	1.754	
Cumulative	0.644		Cumulative	0.622	
KMO	0.815		KMO	0.912	
p-value	0.000		*p*-value	0.000	

7.4 Empirical Results

7.4.1 Qualitative results

This study uses *t*-tests to validate hypotheses 1-6, as shown in Table 7.11, where Pr(|T|>|t|) = 0.0000, much less than 0.05, rejecting the null hypothesis, thereby confirming hypotheses 1–6.

Table 7.11 *t*-test results.

Variable	df	*t*-value	Pr（|T|>|t|）
X6	236	41.414	0.000
X7	236	29.669	0.000
X8	236	32.339	0.000
X9	236	36.327	0.000
X10	236	35.000	0.000
X11	236	44.870	0.000

For Hypothesis 1, information asymmetry and conflicts of interest between higher and lower-level governments can undermine policy implementation. Therefore, higher-level governments must design appropriate incentive mechanisms to motivate lower-level governments to fulfil their responsibilities, address agency issues and enhance policy implementation. Incentive mechanisms linked to environmental benefits allow local governments to gain direct rewards from promoting GBs. For instance, the central government could offer financial transfers or performance bonuses based on the quantity or effectiveness of GB projects implemented by local governments. This approach directly incentivises local governments to promote GBs, compensating for execution costs and serving as a positive motivator.

For Hypothesis 2, developers, as rational economic agents, base their strategies on the intensity of policy incentives to maximise benefits. Incentive mechanisms tied to building greenness establish technical and quality targets for GBs, encouraging enterprises to meet and exceed these standards to receive policy rewards. This promotes innovation in green technology, enhances building quality and drives a green transformation on the supply side.

For Hypothesis 3, the central government delegates public functions to local governments through financial transfers. A high proportion of fixed payments can weaken this agency relationship, reducing local governments' enthusiasm for policy implementation. Therefore, reducing fixed payments while increasing the proportion of incentive-based payments can strengthen the agency constraint between central and local governments, improving policy effectiveness. In executing GBPs, the central government could reduce the fixed component of local financial transfers but maintain incentive payments linked to environmental indicators. This approach increases local governments' returns and revenues from implementing GBPs, raising the costs and risks of non-compliance, thereby enhancing their responsibility and economic interest in promoting GBs, creating a dual incentive.

For Hypothesis 4, the central government should implement differentiated financial transfer and incentive policies based on the varying governance costs of local governments. Higher incentive intensity can yield greater effects in regions with lower implementation costs, compensating for policy execution opportunity costs and motivating local governments to implement policies more enthusiastically. In practice, higher incentives, such as increased financial rewards, could be provided to local governments with lower execution difficulties and costs, enabling them to gain excess benefits while fulfilling environmental responsibilities.

This further enhances such local governments' political and economic motivation to promote GBs, improving their initiative and work enthusiasm.

For Hypothesis 5, low-cost developers, benefiting from resource and technological advantages, encounter less resistance in industrial upgrading and technological innovation. Local governments can foster their investment and innovation by offering higher incentives, such as increased tax exemptions and financial support, thereby enhancing the effectiveness of these measures.

For Hypothesis 6, developers, as rational economic agents, choose their behaviour and technology investment strategies based on the strength of government incentives. Increasing the intensity of incentives, such as enhanced tax breaks and financial support, can improve developers' expected returns from promoting GBs, encouraging them to invest more in green technology R&D and application to achieve excess profits. By strengthening incentive policies, the government can activate and motivate enterprises to invest in advanced GB technologies and materials, continuously improving product sustainability and environmental friendliness. This effectively offsets the high costs of green technology R&D, driving green transformation and industrial upgrading on the supply side.

7.4.2 Quantitative results

Table 7.12 shows the correlations between variables, revealing significant relationships between them.

Table 7.12 Correlation analysis of variables.

	z1	z2	z3	z4	z5	z6	z7	z8	z9	z10	z11	z12
z1	1.000											
z2	0.791***	1.000										
z3	0.820***	0.788***	1.000									
z4	0.872***	0.695***	0.747***	1.000								
z5	0.292***	0.281***	0.211***	0.199***	1.000							
z6	0.266***	0.034	0.150**	0.288***	-0.250***	1.000						
z7	0.794***	0.799***	0.671***	0.773***	0.241***	0.224***	1.000					
z8	0.773***	0.740***	0.633***	0.723***	0.302***	0.266***	0.944***	1.000				
z9	0.839***	0.859***	0.764***	0.760***	0.220***	0.249***	0.858***	0.816***	1.000			
z10	0.856***	0.775***	0.822***	0.845***	0.242***	0.266***	0.739***	0.688***	0.818***	1.000		
z11	0.340***	0.198***	0.379***	0.357***	-0.064	0.332***	0.252***	0.230***	0.186***	0.369***	1.000	
z12	0.448***	0.234***	0.344***	0.423***	0.074	0.388***	0.420***	0.389***	0.341***	0.453***	0.802***	1.000

Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

To quantitatively test the earlier hypotheses, this study employs an OLS regression model, with demographic characteristics included as control variables.

Table 7.13 Linear regression results of central government's strict supervision and participation of local governments and developers.

	(1)	(2)
	z2	z3
z1	0.754***	0.773***
	(19.827)	(21.929)
N	237	237
R2	0.624	0.670

Note: *t*-values in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

To test Hypothesis 7, the regression results are presented in Table 7.13. The central government's initiative in implementing strict supervision is significantly positive at the 1% level, indicating a strong positive correlation between the central government's stringent oversight and the participation of local governments and developers in promoting GBs. As the highest authority, the central government's policy decisions create significant ripple effects, influencing subordinate local governments and related enterprises. When the central government decides to strengthen energy-saving and environmental protection regulations in the construction industry through stricter and more mandatory policies, it sends a clear signal to local governments and developers, compelling them to take proactive measures to promote GBs and achieve environmentally sustainable development. As executors of central policies, local governments and developers are inevitably prompted to respond to these regulatory changes by increasing investments, improving action plans, ensuring compliance and actively engaging in promotion and practice to avoid penalties. Thus, the central government's stringent supervision effectively stimulates the initiative of local governments and enterprises, advancing the progress of GB development in China.

Table 7.14 Linear regression results of central government's penalty for collusion and participation of local governments and developers.

	(1)	(2)
	z2	z3
z4	0.592***	0.630***
	(14.831)	(17.232)
N	237	237
R2	0.481	0.556

Note: *t*-values in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

To verify Hypothesis 8, the regression results are presented in Table 7.14. The central government's punitive measures against collusion are significantly positive at the 1% level, indicating a positive correlation between these measures and the participation of local governments and developers in promoting GBs. The strict enforcement of anti-collusion policies enhances the central government's authority and legitimacy in environmental regulation, sending a clear message to all levels of government and enterprises to act with integrity and comply with regulations. The increased cost of non-compliance due to severe penalties encourages honest compliance and active promotion of GB initiatives. Rational actors, such as local governments and developers, respond to these enhanced regulations by adjusting their strategies to meet central environmental standards, thereby reducing the risks and costs associated with dishonest practices.

Table 7.15 Linear regression results of central government's reward and penalty strength and participation of local governments and developers in different implementation cost scenarios.

	(1)	(2)
	z2 (high-cost)	z3 (low-cost)
z6	0.668^{***}	-1.047^{***}
	(13.541)	(-20.129)
N	154	83
R2	0.544	0.831

Note: *t*-values in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

To verify Hypotheses 9 and 10, the regression results are displayed in Table 7.15. The central government's reward and penalty intensity is significantly positive in regions with high implementation costs and significantly negative in regions with low implementation costs. This suggests that the strength of the central government's rewards and penalties is positively correlated with local governments' participation in promoting GBs in high-cost regions, while it is negatively correlated with developers' participation in low-cost regions. The central government tailors its reward and penalty strategies based on the implementation difficulties and costs faced by local governments. In high-cost regions, more intense rewards and penalties are necessary to motivate compliance and promote policy execution. However, in low-cost regions, overly strict rewards and penalties may have adverse effects, potentially discouraging enterprises by making the policy costs appear prohibitive.

Table 7.16 Linear regression results of local government rewards to developers and consumers and developers' participation.

	(1)	(2)	(3)
	z3	z3	z3
z7	0.553^{***}	-	0.554^{***}
	(13.867)	-	(4.557)
z8	-	0.481^{***}	-0.001
	-	(12.548)	(-0.006)
N	237	237	237
R2	0.448	0.399	0.445

Note: *t*-values in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

To verify Hypothesis 11 and sub-hypotheses 11(a) and 11(b), the regression results are shown in Table 7.16. Rewards provided by local governments to developers and consumers are both significantly positive. However, according to column (3), when both variables are included in the model, rewards for developers are more significant, indicating that rewards targeting developers are more effective in encouraging them to actively promote GBs than those aimed at consumers. As key stakeholders, developers base their GB promotion strategies on the incentive policies offered by the government. Incentive measures directed at developers have a more immediate impact on their decisions and actions compared to those aimed at consumers, as developers are the primary suppliers who closely monitor governmental industrial policies. By offering tailored incentives to developers, local governments can more effectively mobilise their efforts to promote GBs. These incentives, including policy support and subsidies, directly boost developers' motivation to engage in GB initiatives, playing a significant positive role. In contrast, consumer-directed incentives tend to have a more indirect and weaker impact.

Table 7.17 Linear regression results of local government penalty to developers, central government penalty for collusion and developers' participation.

	(1)	(2)	(3)
	z3	z3	z3
z9	0.602^{***}	-	0.366^{***}
	(18.153)	-	(7.793)
z4	-	0.630^{***}	0.332^{***}
	-	(17.232)	(6.612)
N	237	237	237
R2	0.582	0.556	0.646

Note: *t*-values in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

To verify Hypothesis 12 and sub-hypotheses 12(a) and 12(b), the regression results are presented in Table 7.17. Punitive measures imposed by local governments on developers, as well as the central government's penalties for collusion, both have a significant positive impact, with local penalties exhibiting a larger coefficient. This suggests that local government punitive measures against developers have a stronger positive correlation with developers actively promoting GBs compared to central government penalties for collusion. Both levels of punitive measures positively influence developers' enthusiasm for GB promotion by increasing the cost of non-compliance, thereby compelling social actors to align their behaviours with policy objectives. Although there is a collaborative division of labour between central and local governments, local penalties are more directly and closely tied to the behaviour of local enterprises, making them more targeted and effective. When subject to penalties, developers adjust their GB strategies based on the severity of punitive measures from different levels of government. Local government penalties, being more immediate, have a greater impact on compliance, encouraging adherence to standards as well as proactive, above-standard compliance.

To test Hypothesis 13, the regression results are displayed in Table 7.18. Consumers' willingness to pay for GBs is significantly positive, indicating a strong correlation between this willingness and developers' engagement in promoting GBs. Changes in consumer demand and their willingness to pay influence the production and investment decisions of supply enterprises. When consumers are willing to pay a premium for GBs, it signals robust market demand, prompting real estate companies to actively promote GBs. As profit-driven entities, developers adopt proactive strategies in response to market changes, aiming to meet consumer demand and maximise profits. Consequently, consumer demand and willingness to pay for GBs serve as key drivers for supply-side transformation. This market mechanism guides enterprise behaviour, encouraging the active promotion of GB products. Compared to government-led initiatives, this demand-driven incentive creates a virtuous cycle that supports the widespread adoption of GBs.

Table 7.18 Linear regression results of consumers' willingness to pay for GBs and developers' participation.

	(1)
	z3
z10	0.712^{***}
	(22.135)
N	237
R2	0.674

Note: *t*-values in parentheses; * *p*<0.10, ** *p*<0.05, *** *p*<0.01.

To test Hypothesis 14, the regression results are shown in Table 7.19. The market share of low-cost developers is significantly positive, indicating a strong correlation between the market share of low-cost developers and developers' efforts to promote GBs. As the market share of low-cost developers increases, these developers gain more resources and competitive advantages, enabling them to invest in the quality of GBs. By achieving economies of scale, they can reduce the costs associated with GB technologies and materials, which allows them to allocate more resources towards enhancing the quality and sustainability of their projects. A larger market share also amplifies their influence, prompting them to differentiate their offerings further and maintain their competitive position by meeting higher environmental standards and innovating in green technology. This rise in market share among low-cost developers intensifies competition, compelling high-cost developers to enhance the quality of their GBs to justify their higher prices and maintain market dominance. The overall market standard for GBs improves as developers, regardless of their cost structure, strive to meet rising consumer expectations for quality and sustainability. This competitive dynamic fosters a cycle of continuous improvement, where both low- and high-cost developers are driven to innovate and elevate the quality of GBs, ultimately leading to an industry-wide enhancement of standards.

Table 7.19 Linear regression results of low-cost developers' market share and developers' efforts.

	(1)
	z12
z11	0.761***
	(20.600)
N	237
R2	0.642

Note: *t*-values in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

7.5 Chapter Summary

This chapter formulates 14 research hypotheses based on the mathematical analyses presented in Chapters 5 and 6 and subsequently designs measurement items and a questionnaire survey. Data are collected through the questionnaire survey, and the reliability and validity of the data are rigorously tested. *t*-tests and OLS regression analyses are then employed to empirically examine the factors influencing GB promotion. The findings confirm that the empirical results align with the mathematical conclusions from Chapters 5 and 6, thereby affirming the stability and reliability of the study's outcomes.

CHAPTER 8 Policy Implications for GB Promotion

8.1 Introduction

China's vast geographical expanse and regional disparities in economic levels and characteristics have resulted in varying stages of GB development across the country. Some regions have made significant strides in promoting GBs, achieving initial success in large-scale development. These regions have actively responded to national policies, driving extensive GB projects and gradually establishing corresponding support systems and technical standards. However, despite progress in scaling up, there remains room for improvement in pursuing high-quality development. Simultaneously, other regions have yet to reach large-scale GB development, with the construction market still dominated by TBs and GB promotion and implementation remaining relatively limited. In these areas, there is a need for enhanced governmental policy guidance and support to achieve scale effects and lay a solid foundation for future high-quality development.

The differing GB development needs across regions have established the foundation for a phased approach to policy implementation. In regions where large-scale development has been achieved, policies will gradually shift towards enhancing building quality and promoting high-quality GB development. In regions where large-scale development is still emerging, policies will focus on promoting GB scale expansion to provide necessary support and guidance. This phased strategy allows for the rational allocation of resources based on local conditions, fostering comprehensive GB development while offering targeted support and guidance for high-quality development in different regions. Through orderly and phased advancement, sustainable GB development can be realised nationwide.

Chapter 5 analysed the impact of various factors on the ideal evolutionary path and speed by constructing a tripartite evolutionary game model involving the central government, local governments, and developers. Under the ideal path, all local governments and developers gradually evolve towards the full implementation of GBPs and the construction of GBs, corresponding to the large-scale promotion of GBs in real-world scenarios. Chapter 6, through the construction of a dual principal-agent model, designed optimal policy incentive mechanisms under information asymmetry, maximising local and developer efforts in green initiatives, ensuring the quality of GBs and providing theoretical support for incentivising high-quality GB development. Chapter 7 empirically validated the mathematical models presented in Chapters 5 and 6. Accordingly, this chapter proposes policy implications for promoting both the large-scale and high-quality development of GBs based on the GBP framework outlined in Chapter 4, the theoretical analyses in Chapters 5 and 6 and the empirical evidence in Chapter 7.

8.2 Policy Implications for Large-Scale Promotion of GBs

8.2.1 Central government's role in leading with "strict supervision"

The promotion of GBs in China is a top-down process, with the central government playing a crucial guiding role. The theoretical model in Chapter 5 reveals that local governments and developers will only evolve towards fully implementing GBPs and developing GBs once the central government has first reached a "strict supervision" equilibrium (see Observation 5.1), thereby achieving large-scale promotion of GBs. However, within the existing framework in China, the central government has yet to implement strict supervision across regions, as evidenced by the low enforcement intensity of RBPs and the lack of standardised regulatory procedures and guidance measures. Therefore, to foster the adoption of GBs, the central government needs to first signal its intent to supervise the GB market strictly and enhance regulatory measures. This would eliminate the opportunistic tendencies and collusion among local governments and developers, encouraging them to fully implement policies and construct GBs. Specifically, the central government can adopt various measures to enforce strict supervision, such as intensifying special inspections of local governments, establishing regulatory platforms, improving the quality of regulatory personnel and utilising emerging technologies.

First, the central government should establish dedicated GB regulatory agencies or departments, employing a "dual random selections plus timely release of results" mechanism for inspections. This could involve reviewing documents, conducting on-site inspections, interviews, data analysis, investigating reports and random sampling to carry out special inspections of local governments' GB initiatives. Inspection content should include (1) completion of GB targets, such as whether the goals set in the plans have been met and whether there are any cases of data falsification or misreporting; (2) the formulation and effective implementation of relevant supporting policies by local governments, such as the establishment of incentive mechanisms, the conduct of related publicity, the establishment of dedicated GB institutions and the development of comprehensive GB standards; (3) the existence of any irregularities in the approval and management processes of GB projects, such as document falsification or non-compliance with project quality standards; (4) issues in GB supervision and evaluation, such as regulatory loopholes or inaccurate evaluation results. To ensure the effectiveness of these inspections, the central RBPs, such as those outlined in the Ministry of Housing and Urban-Rural Development's "*Notice on Special Inspections of GB Implementation*", should avoid notifying regions in advance of random checks. This measure would prevent local governments from fabricating results to meet inspection requirements, ensuring the quality and effectiveness of GB initiatives. Additionally, the central government should increase the frequency of these special inspections and publish the results, urging local governments to publicly disclose their corrective actions based on the inspection outcomes. To ensure the smooth implementation of the aforementioned regulatory mechanisms, it is recommended that the central government expedite the issuance of detailed implementation rules for special inspections of GB implementation, clarifying specific measures and requirements and standardising the inspection process to ensure thorough supervision. Simultaneously, the central government should strengthen the regulatory workforce, enhancing training efforts and promoting ethical standards to prevent fraudulent practices. Improving professional skills through training and experience-sharing sessions would also be beneficial.

Second, a national GB regulatory platform should be established, characterised by transparency and openness. This platform should make the results of special inspections, regional policy documents, work reports and project information publicly available and provide a platform for local governments and enterprises to upload relevant information. Through this platform, the central government could better monitor regional policy implementation and ensure compliance. The platform should include various forms of information, such as text, images, audio and video, with relevant classification, tagging and search functions for user convenience. Enterprises and local governments would need to back up and upload information on the construction status of GB projects, statistical data, photographs from the construction process, acceptance documents and energy consumption data, allowing the central government to review and verify this information at any time. By integrating published policy documents with implementation status, the platform could provide a comprehensive assessment of regional GBP implementation, helping the central government better understand local compliance and adjust and refine policies as needed. Additionally, the platform should offer anonymous reporting and complaint services for the public and enterprises, promptly addressing issues and enhancing the transparency and credibility of government oversight.

Moreover, the central government could leverage emerging technologies such as blockchain and artificial intelligence to provide more convenient, efficient and accurate regulatory tools for the GB industry, thereby improving regulatory efficiency. For instance, blockchain technology, as a decentralised distributed ledger, could enhance the transparency and traceability of the approval and management processes for GB projects, preventing irregularities such as document falsification or non-compliance with project quality standards. By integrating approval documents and regulatory data into the blockchain, the integrity of information could be ensured, thereby improving regulatory effectiveness and credibility. Additionally, artificial intelligence, as an intelligent technology, could monitor and analyse public opinion online through big data analysis and natural language processing, promptly identifying negative sentiment in the GB industry and tracking the actions of relevant local governments and enterprises.

8.2.2 Central government's regional reward and penalty mechanism, with severe penalties for collusion between local governments and enterprises

When formulating GBPs, the central government should consider the economic development levels, resource endowments, industrial structures and the costs and benefits of implementing these policies across different regions, adopting differentiated incentive mechanisms to achieve policy objectives.

First, support should be provided to less developed regions. For underdeveloped regions, such as some provinces in the central and western parts of China, the cost of fully implementing is higher due to their relatively low levels of economic development, insufficient resource allocation and land use constraints. If the central government's rewards and penalties are inadequate, these regions may selectively implement policies (see Observation 5.2). Therefore, to advance the large-scale promotion of GBs, the central government should offer greater incentives (such as transfer payments, career promotions, etc.) to these regions to offset the cost disadvantages of policy implementation and alleviate the financial pressures associated with full policy implementation. At the same time, penalties for "partial implementation" behaviours should be increased to deter non-green practices and enhance the motivation for fully implementing. For example, the central government could reduce future transfer payments or restrict spending on other projects and strengthen administrative accountability, thereby increasing the cost of non-compliance.

Second, guidance should be provided to more developed regions. For more developed regions, such as certain provinces in the eastern part of China, where higher levels of economic development, more complete infrastructure and more advanced technological capabilities exist, the cost of fully implementing is moderate. Excessive rewards or penalties could slow down or even hinder large-scale development (see Observations 5.7 and 5.9). In this case, the central government should appropriately limit the rewards for “full implementation” or the penalties for “partial implementation” in these regions. This would avoid unnecessary fiscal expenditure and prevent overly stringent policies from slowing down the pace of large-scale development, thereby ensuring the smooth advancement of GBPs at the local level and accelerating large-scale promotion.

Furthermore, increasing penalties for collusion would accelerate the evolution of all parties towards the ideal equilibrium (see Observation 5.8). Therefore, the central government should impose strict penalties on any collusion between local governments and enterprises to prevent opportunistic behaviours. Specifically, a joint punishment mechanism could be established, jointly sanctioning local governments and developers suspected of collusion. Measures such as political demotion, fines, suspension of operations, revocation of business licenses, public exposure, “lifelong accountability” and revocation of certifications could serve as a deterrent to local governments and developers, encouraging more regions and developers to engage in GB construction actively.

8.2.3 Strengthening local government’s rewards and penalties for developers

Compared to incentivising consumers, directly rewarding developers on the supply side can prompt them to accelerate the transition towards GB construction (see Observation 5.6). Similarly, rather than penalising collusion, directly penalising developers for non-green practices can hasten their evolution towards constructing GBs (see Observation 5.11). When purchasing buildings, consumers often focus on price and quality, with relatively low awareness and demand for environmental sustainability. However, developers, as the producers of GBs, can directly influence the environmental quality of buildings by choosing eco-friendly materials and energy-efficient equipment. Therefore, under resource constraints, local governments can more effectively encourage developers to prioritise environmental sustainability during construction by directly rewarding and penalising them, thereby enhancing the efficiency of GBPs.

Specifically, local governments should clarify the subjects and amounts of rewards within FSPs and strengthen the establishment of developer incentive systems. For instance, Sichuan Province's FSPs mention rewards for GB projects but have yet to establish clear reward mechanisms, lacking specific policy targets and measures, which weakens the incentives. To increase the strength of policy incentives, it is essential to first identify the targets and measures of incentives, including but not limited to providing subsidies, floor area ratio bonuses, priority in awards, tax incentives and credit support to developers. Additionally, efforts should be made to enhance the support for these incentive measures, such as increasing the reward amounts for GBs, reducing corporate income tax for green developers and raising green loan limits. On the other hand, the enforcement of GB regulations varies across provinces, with regulatory intensity being uneven. To enhance regulatory enforcement, local governments should expedite the formulation and implementation of RBPs, such as enacting and promulgating mandatory "*Green Building Regulations*" that clearly define the responsibilities and penalties for non-GBs. For example, developers violating GB ordinances could face fines, with the amounts gradually increasing based on the severity of the violations. For developers repeatedly violating GB regulations, the government could revoke their development qualifications. Additionally, governments could impose environmental taxes on non-green developers to increase their tax burden, encouraging their transition towards the GB sector.

8.2.4 Guiding consumers to increase their willingness to pay for GBs

Consumers' willingness to pay for GBs significantly influences developers' behaviours. If consumers show insufficient enthusiasm for GBs, government policies will struggle to effectively drive developers to implement green measures (see Observation 5.12). To guide consumers towards increasing their willingness to pay for GBs, the government can optimise existing SBPs, RBPs, TSPs and FSPs. SBPs help consumers understand the advantages of GBs, RBPs protect consumer rights, TSPs ensure the quality and performance of GBs, and FSPs reduce the financial burden of purchasing GBs.

First, optimising SBPs should focus on consumer education and awareness. Governments at all levels can enhance consumers' understanding of the benefits of GBs by organising lectures and seminars, publishing information and establishing information platforms. For example, providing case studies and data on GBs, illustrating the advantages of completed GBs in terms of operational costs, energy and water consumption compared to TBs, can help consumers more comprehensively understand the economic and environmental benefits of GBs, thereby increasing their willingness to pay. Additionally, emphasising the long-term sustainability of GBs, such as operational cost savings and property appreciation, can help consumers better recognise the investment value of GBs, further enhancing their willingness to pay. Moreover, providing detailed information on GBs for sale, introducing estimated future value and advantages over TBs, and showcasing these through virtual reality and model homes can help consumers tangibly appreciate the benefits of GBs. Additionally, pilot programs for GB inspections could be introduced, guiding consumers in the inspection process, thereby increasing their involvement and trust and promoting consumer awareness and acceptance of GBs.

Second, within RBPs, developers should be required to display the grade of GB projects at sales sites clearly and include GB grades, corresponding technical measures and green performance indicators in property sales contracts, quality guarantee certificates and usage manuals. This would provide legal protection for the rights of GB consumers and prevent developers from engaging in opportunistic behaviours, such as false advertising, due to information asymmetry.

Third, improving TSPs should focus on relevant standards. For example, accelerating the establishment and improvement of "*Green Building Construction Standards*" and "*Green Building Completion Acceptance Standards*" in various regions. Existing local standards mainly focus on evaluation criteria, with insufficient local construction and acceptance standards, leading to consumer scepticism about the "greenness" of market products. Furthermore, the introduction of new evaluation standard systems necessitates the rapid development and refinement of regional GB evaluation and certification frameworks to ensure quality and performance. Providing consumers with reliable information will enhance trust, enabling them to assess GB effectiveness accurately and increasing their willingness to pay.

Finally, FSPs should focus on the development of green finance. Financial institutions should be encouraged to provide preferential loans and investments for GB projects. With the support of financial institutions, consumers will find it easier to obtain the necessary funds to purchase GBs. Additionally, insurance companies should be encouraged to offer construction quality insurance for GBs, gradually improving construction quality assurance and warranty mechanisms, thereby reducing the risk costs for consumers purchasing GBs. Moreover, the government could offer preferential housing provident fund loan amounts to consumers, further increasing their willingness to pay.

8.3 Policy Implications for Promoting High-Quality GBs

8.3.1 Strengthening information disclosure for local governments and developers

The accurate information held by local governments and developers significantly influences the policy design of central and local governments. When local governments and developers have an information advantage, they may, driven by self-interest, make decisions detrimental to the interests of central and local governments. In the long term, information asymmetry may lead to inefficient resource allocation, hindering the high-quality development of the GB sector. Therefore, the central and local governments must fully recognise the value of information and take corresponding measures to minimise the negative impact of information asymmetry. This can be achieved by enhancing information collection and utilisation, thereby improving the effectiveness of policy formulation.

Specifically, a GB information disclosure platform should be established as part of SBPs, supported by RBPs such as information disclosure laws, which mandate local governments and developers to disclose relevant information on the platform. This information may include sources of building materials, energy-saving design plans and project progress, thereby curbing the moral hazards of local governments and developers. Additionally, efforts should be made to strengthen data verification to prevent data falsification and improve data quality. Local governments and developers should also be encouraged to disclose information through multiple channels, such as websites, social media, exhibitions and press conferences, to enhance transparency.

Moreover, raising the entry threshold for GB developers is an effective means of information filtering. Strict standards and requirements should be established to audit and evaluate developers' qualifications, assets and personnel, ensuring their capability and capacity to undertake GB projects. For instance, developers may be required to have a certain level of GB experience, as well as relevant technical qualifications and certifications. Additionally, a credit assessment mechanism could be implemented to evaluate and monitor developers' reputation, compliance and financial status, thereby reducing risks and enhancing their credibility.

8.3.2 Establishing context-specific incentive mechanisms for fair incentivisation

In FSPs, context-specific incentive mechanisms should be established to achieve fair incentivisation. The central government aims to promote the development of high-quality GBs by encouraging local governments to implement them. Therefore, local benefits must be linked to the environmental benefits derived from promoting high-quality GBs. Given China's regional disparities, the central government needs to consider the costs of green efforts, risk aversion, market size and disturbances when designing incentive contracts. This will allow the determination of appropriate incentive rewards (fixed payments) and benefit-sharing ratios (incentive intensity) for different regions, avoiding the inefficiencies of a "one-size-fits-all" approach (refer to Lemmas 6.4 and 6.8).

Unlike large-scale promotion policies, the sensitivity analysis of the theoretical model in Chapter 6 (see Figure 6.4) suggests that to encourage local governments to implement high-quality development strategies, the central government should offer higher incentive intensity and fixed payments to regions with strong green development capabilities (lower unit green effort costs). This would allow these regions to benefit directly from promoting high-quality GBs, thereby motivating them to continue their exemplary role in the GB sector. For regions with weaker development capabilities, where resource and technological limitations result in higher unit effort costs, the central government should reduce their benefit-sharing ratios and fixed payments. Providing higher incentives solely due to underdevelopment could lead to the inefficient use of fiscal resources, as such incentives may not effectively motivate the region or improve the quality of its GBs. Instead, the central government could send professional technical teams to the area, support the establishment of partnerships between less developed and developed regions and promote learning and exchange. This approach would enhance governance and technical capacity in less developed regions, narrowing the gap with more developed areas. This strategy would avoid wasting fiscal resources while enabling less developed regions to play a more significant role in GB and achieve sustainable development.

For local governments, encouraging developers to enhance the quality of GBs requires establishing incentive mechanisms that link developers' benefits directly to the greenness of buildings and provide differentiated incentive contracts based on developers' cost types. The current incentive mechanisms are primarily based on the GB star rating system, divided into four levels. For example, in Shanghai, a two-star GB operation label project receives a reward of 50 CNY/m², while a three-star project receives 100 CNY/m². However, this mechanism has a flaw: there is significant variation in the greenness within the same level, leading to a lack of motivation for developers to improve building greenness. Therefore, a more refined incentive mechanism should be adopted, using building greenness as the incentive standard and awarding developers based on their scores in the evaluation system.

Additionally, when formulating incentive contracts, local governments must consider their and developers' effort costs, risk aversion, market size and disturbances to determine appropriate incentive rewards (fixed payments) and benefit-sharing ratios (incentive intensity) for different developers, rather than simply copying standards from other regions. Particularly, local governments should offer different contracts for developers to choose from, enabling developers with varying costs to select contracts that suit their actual circumstances, thereby achieving information disclosure (refer to Lemmas 6.3 and 6.7). For low-cost developers, local governments should provide higher incentive intensity and fixed payments, encouraging them to choose contracts that align with their actual information and motivating them to improve GB quality (refer to Corollaries 6.1.2, 6.3.1, 6.5.2 and 6.7.1). Such an incentive mechanism would be more aligned with the actual conditions of developers in the market, forming a relatively fair mechanism while curbing developers' "free-riding" behaviour (refer to Corollaries 6.1.3 and 6.5.3).

Finally, central and local governments should focus on the dynamic adjustment of incentive mechanisms. When the GB market and related influencing factors change, timely adjustments should be made to enhance the efficiency and effectiveness of policy implementation, ensuring the sustainability and adaptability of policies. For example, when risk aversion increases, it may be appropriate to lower the incentive intensity (see Figure 6.8). This is because, in an unstable market environment, developers and local governments have reduced risk tolerance, leading them to take cautious actions and focus more on short-term benefits rather than long-term development. In such a scenario, overly emphasising the high-quality promotion of GBs and increasing incentive intensity could lead to speculative behaviour by local governments or developers, resulting in inefficient policy implementation, wasted fiscal resources and potentially counterproductive outcomes.

8.3.3 Enhancing central government's top-level design

In promoting the high-quality development of GBs, the central government should primarily use incentives to engage local governments fully. However, it is crucial to consider the potential for collusion between local governments and developers, where they might falsely report environmental benefits to enhance performance records. To mitigate this, the central government should maintain the existing profit-sharing ratio (incentive intensity) with local authorities but reduce fixed payments. Instead, more payments should be based on actual environmental benefits. This approach can reduce the motivation for collusion while safeguarding the central government's interests, environmental benefits and overall social welfare (refer to conclusions 6.1, 6.2, and 6.4).

Besides rewards, in the process of promoting high-quality GBs, the central government should use constraints as a supplement, enhancing supervision and punishment of collusion when necessary. This can be achieved by establishing stricter regulatory mechanisms and imposing more severe penalties for false reporting of environmental benefits. For instance, the government could cancel support policies or restrict companies that falsely report environmental benefits from participating in tenders, thereby reducing the motivation for collusion. The severity of penalties should be proportional to the incentive intensity and the extent of false environmental reporting, ensuring that those engaging in speculative behaviour face higher risks and penalties.

To implement these measures effectively, the central government needs to establish a comprehensive GB environmental performance assessment mechanism and issue the "*Green Building Environmental Performance Evaluation Measures*". This mechanism would provide quantitative standards for rewards and penalties by quantifying the environmental benefits of GBs. The central government can organise experts, scholars and industry professionals to develop a scientific and comprehensive performance evaluation index system for GBs, which should include aspects such as building energy consumption, water resource utilisation, greening and indoor environmental quality. These indicators should be objective, comparable and operable to provide accurate environmental performance data for the government and society.

Additionally, independent third-party institutions could be introduced to test and evaluate the environmental benefits of GB projects. This would reduce the likelihood of collusion and false reporting while enhancing the credibility and fairness of the assessment results. Such institutions could be either independent entities or consortia of multiple organisations possessing the necessary qualifications and technical capabilities to perform environmental assessments of GBs. The government could stipulate in tender documents that GB projects must undergo environmental performance testing and evaluation by certified third-party institutions. This would increase demand for environmental performance testing among project applicants and stimulate competition in the third-party assessment market.

8.3.4 Encouraging developers to innovate green technologies

Reducing the development costs of GBs and increasing the market share of low-cost developers can bring more economic, environmental and social benefits to the central government (refer to Figures. 6.3 and 6.7). Therefore, the government should actively support the research and innovation of green technologies, promoting the transformation and upgrading of the construction industry towards green and sustainable practices.

In terms of DBPs, the government can guide the establishment of GB technology consulting services. These services aim to provide developers with technical consultation and solutions to help improve the quality of GBs and reduce their costs. Furthermore, the government should encourage and support the deep integration of industry, academia and research within the GB sector, fostering the formation of GB industry alliances to promote collaboration across the industry chain, thereby reducing costs and increasing the proportion of low-cost developers in the market. For example, in 2022, under the leadership of the China Association of Building Energy Efficiency, leading companies like China Overseas Land & Investment and renowned institutions like Youlu Green Intelligence initiated the establishment of the Low-Carbon Healthy Real Estate Professional Committee. By 2022, this committee had 25 outstanding companies from the real estate industry and its upstream and downstream sectors as members, with an advisory group composed of renowned experts, including academicians from the Chinese Academy of Sciences and the Chinese Academy of Engineering.

Moreover, establishing international cooperation mechanisms for GBs is essential to guide and encourage collaboration between domestic and foreign enterprises, fostering the exchange and dissemination of GB technologies and expertise. For instance, the government can support and provide international training programmes for GBs, facilitating developers' participation in overseas GB courses to enhance their technical and knowledge levels. Establishing an international GB technology transfer centre can further assist developers in acquiring, converting and applying GB technologies and experiences from abroad, reducing the costs associated with learning foreign GB technologies.

At the same time, FSPs and SBPs should be improved to support green technology innovation among developers. In terms of FSPs, measures should be taken to ensure the goals outlined in DBPs are met. This could involve increasing financial investment in green technologies and policy support, encouraging universities, research institutions and enterprises to jointly undertake GB technology research projects to enhance innovation capacity and competitiveness and promoting the conversion of scientific and technological achievements into practical applications. Regarding SBPs, the government should increase the availability of GB technology training and consulting services to developers, helping to lower the costs of developing high-quality GBs. For example, the government could offer customised GB technology training to developers, strengthening their technical and knowledge reserves in GB design, material selection and construction. It could also provide case studies from benchmark companies like Landsea Group and Wanda Group, as well as international best practices and organise domestic and international seminars and exhibitions to facilitate the exchange of advanced GB technologies and experiences. Furthermore, efforts should be made to enhance the application process for projects like the "National Construction Industry Scientific and Technological Achievement Evaluation and Promotion Project—Green Building Special Technologies and Products," promoting the conversion of GB technologies into applicable products and advancing the adoption of suitable technologies.

8.4 Chapter Summary

Regional inequalities have shaped the policy framework for the phased promotion of GBs in China. Based on the policy analysis in Chapter 4, the theoretical model analysis in Chapters 5 and 6 and the empirical verification results in Chapter 7, this chapter presents policy implications for the large-scale and high-quality promotion of GBs as follows:

1. To advance large-scale GB development, the central government should first implement strict supervision, leveraging its leadership role within China's top-down policy system. Secondly, the central government should determine the varying levels of rewards and penalties based on the cost differences of implementing policies across regions. Specifically, regions with higher costs should receive increased rewards and penalties, while those with lower costs should see a reduction. However, in all regions, the central government must intensify penalties for collusion. Thirdly, local governments should focus on incentivising developers on the supply side, prioritising rewards and penalties to improve policy efficiency. Fourthly, both central and local governments should work to increase consumers' willingness to pay, establishing a market-driven and sustainable promotion mechanism.
2. To advance the high-quality development of GBs, information disclosure by local governments and developers must be enhanced to minimise the adverse effects of information asymmetry. Secondly, central and local governments should establish tailored incentive mechanisms based on the actual conditions of incentive recipients, ensuring equitable incentives. Unlike the policy recommendations for large-scale development, the central government should provide stronger incentives to regions with lower implementation costs while reducing incentives for regions with higher costs. Thirdly, the central government should primarily use incentives, with constraints as a supplement, to curb collusion. Fourthly, both central and local governments should encourage developers to innovate green technologies, increasing the market share of low-cost developers to achieve greater economic, environmental and social benefits.

CHAPTER 9 Conclusions

9.1 Introduction

This chapter first revisits the research aim and objectives to assess the extent to which they have been achieved. Subsequently, the key research findings are synthesised, highlighting their contributions to the academic body of knowledge and practical implications for the industry. Finally, the limitations and future studies are discussed.

9.2 Review of Research Objectives

Promoting GBs is a key measure for energy conservation and emission reduction in the construction industry and plays a crucial role in supporting China's dual-carbon goals. This requires effective GBPs in China's MLG system, leading to the following four research objectives.

(1) To examine the current state of GBPs and identify the key characteristics and challenges of GBP system in China.

(2) To develop a tripartite evolutionary game model and investigate the dynamic behaviours of stakeholders and potential pathways.

(3) To establish a dual principal-agent model for designing the optimal policy incentive mechanisms.

(4) To empirically verify the proposed models and propose policy implications.

Chapter 2 provided a comprehensive literature review on GB promotion, GBPs and MLG, establishing the foundation for the research. Chapter 3 outlined the research design, methodologies and analytical techniques employed. To achieve Objective 1, Chapter 4 provided an in-depth analysis of the evolution of China's GBPs, examining the characteristics and challenges of the GBP system from the perspectives of government level, spatial-temporal distribution and the historical evolution of policy content, structure and intensity. To achieve

Objective 2, Chapter 5 investigated the behavioural mechanisms and pathways of the central government, local governments and developers within China's MLG system, using a tripartite evolutionary game model to examine decision-making patterns under information asymmetry. To achieve Objective 3, Chapter 6 developed a dual principal-agent model to design optimal policy incentive mechanisms for central and local governments, facilitating collaboration among stakeholders and the adoption of high-quality GBs. To achieve Objective 4, Chapter 7 formulated hypotheses based on theoretical models, validated them through surveys using qualitative and quantitative methods, and Chapter 8 provided policy recommendations for large-scale and high-quality GB development, drawing on the theoretical and empirical findings.

9.3 Summary of Research Findings

The key findings are highlighted below.

First, a database comprising 1,727 GBP documents at various levels in China was constructed. The evolution of China's GBPs was systematically analysed from four dimensions: policy quantity, content, structure and intensity, with a spatial comparison identifying the characteristics and development challenges of the policy system. The study found that China's GBPs can be divided into three stages: "Infancy and Exploration" (2004–2005), "Rapid Development" (2006–2015) and "Further Enhancement" (2016–2023). Each stage features unique policy content, intensity and structure, with gradual strengthening and system improvement. Spatially, central and local governments have shown different preferences in policy quantity, structure and intensity: the central government favours DBPs, the eastern region prefers FSPs, and the central and western regions favour RBPs and TSPs. Despite regional differences, both central and local governments place high importance on implementing FSPs. Overall, China's GBP system is characterised by a top-down command pattern with a "carrot-and-stick" approach. However, it still faces challenges, such as conflicts of interest and non-cooperative games under MLG, regional inequalities (with the eastern region outperforming the central and western regions) and the lack of effective incentive mechanisms.

Second, based on evolutionary game theory and the characteristics of GBP system, a behavioural model was established within a MLG structure to promote GBs. The model analysed the behavioural mechanisms and evolutionary pathways among the central government, local governments and developers, exploring the impact of various factors, such as government rewards and penalties. It proposed an ideal promotion pathway and the conditions for its formation. The study found that the behaviours of the three parties interact dynamically. When the central government strengthens its supervision willingness, more local governments and developers are likely to fully implement GBPs and construct GBs. However, local governments' proactive implementation of GBPs does not necessarily encourage developers to actively develop GBs. The promotion system can form different evolutionary pathways under various conditions. To form an ideal pathway where all three parties collaborate to promote GBs, the central government needs to take the lead by evolving towards "strict supervision". Additionally, the promotion system can only achieve the ideal pathway if the incentive mechanisms are properly configured. For example, increasing penalties for collusion and developers can accelerate the system's evolution towards the ideal equilibrium, but excessively high rewards and penalties for local governments may hinder collaborative GB promotion. Moreover, costs, market factors and the degree of building greenness constrain the formation of the ideal pathway.

Third, drawing on principal-agent theory and the ideal promotion pathway, a policy incentive model was developed within an MLG framework to promote GBs. The model formulated optimal policy incentive contracts under conditions of information asymmetry, addressing both scenarios where collusion between the local government and the developer exists and where it does not. These contracts were designed to achieve effective information screening and to maximise green efforts from both the local government and the developer. This study found that the central government's optimal incentive intensity remains unchanged regardless of collusion, although fixed payments decrease, resulting in equivalent benefits, environmental outcomes and social welfare as in the absence of collusion. By structuring appropriate incentive mechanisms, the central government is able to mitigate the adverse effects of collusion. The local government provides greater incentive intensity and higher fixed payments to the low-cost developer compared to the high-cost one, thereby ensuring effective information screening. The optimal incentive intensity for the local government is positively correlated with that of the central government, though it remains consistently lower. Furthermore, increasing the market share of low-cost developers amplifies the central government's optimal incentive contract, while its influence on the local government's optimal contract depends on the developer's cost structure. Additionally, the green effort cost coefficients for both the local government and the high-cost developer, along with their respective levels of risk aversion, further constrain the intensity of the optimal incentive.

To further support the theoretical models, an empirical analysis was conducted to validate the robustness of the proposed frameworks. 14 research hypotheses, derived from the mathematical models, were formulated and tested using survey data collected through rigorously designed questionnaires. Both qualitative and quantitative methods were employed, including *t*-tests and OLS regression analyses. The empirical findings corroborated the theoretical results, demonstrating consistency between the data and the predictions made by the models. This consistency between the empirical data and mathematical models reinforces the credibility of the proposed policy incentive mechanisms and their potential impact on promoting GB initiatives.

Last, based on the analysis of policy texts, theoretical models and empirical findings, policy implications for the large-scale and high-quality promotion of GBs were formulated. To facilitate large-scale adoption, four key policy recommendations were proposed: (1) the central government should assume a leadership role with "strict supervision"; (2) balanced incentives should be provided across regions with stringent penalties for collusion between governments and developers; (3) local governments should enhance rewards and penalties for developers and (4) consumers should be encouraged to increase their willingness to pay for GBs. To promote high-quality development, four recommendations were made: (1) improving information disclosure by local governments and developers; (2) establishing tailored incentive mechanisms; (3) enabling the central government to lead with incentives supplemented by constraints and (4) encouraging developers to innovate in green technologies.

9.4 Contributions of the Research

9.4.1 Theoretical contributions to the knowledge

Significant theoretical advancements are made through a comprehensive analysis of China's GBP evolution from 2004 to 2023. By employing a mixed content analysis—integrating text mining, content analysis and both qualitative and quantitative approaches—this study reveals intricate details of policy dynamics, including policy intensity, structural shifts and regional disparities. This nuanced understanding enriches the literature on GBP, offering a clearer framework for analysing GBP development in MLG contexts. It also provides insights into the evolving roles and strategies of central and local governments, addressing a critical gap in the understanding of MLG dynamics in sustainable development.

The introduction of a tripartite evolutionary game model serves as a theoretical breakthrough, analysing the strategic interactions among central and local governments and developers. This model uncovers the behavioural mechanisms that facilitate or impede GB promotion under conditions of information asymmetry, advancing the theory of stakeholder interaction within

MLG. By focusing on the dynamics of cooperation, conflict and strategic decision-making among multiple actors, the study clarifies how decentralised governance affects policy outcomes and stakeholder behaviours, which has been inadequately explored in prior research. Furthermore, the dual principal-agent model developed in this study contributes to the theory of policy incentive mechanisms. Unlike existing studies that treat the government as a monolithic entity, this model acknowledges the central-local tensions and the potential for collusion with developers. Proposing separate incentive structures for collusion and non-collusion scenarios deepens the theoretical understanding of addressing information asymmetry in public policy design, particularly in the context of GB promotion. This contribution adds a new dimension to the theoretical discourse on incentive mechanisms, offering a more context-sensitive approach to aligning stakeholder interests in a MLG system. Empirical testing of the theoretical models further strengthens their validity and applicability. By integrating survey data, the study confirms the robustness of the proposed models and ensures their relevance to real-world governance dynamics. This empirical validation bridges the gap between theoretical constructs and observed practices, providing a more grounded theoretical contribution.

9.4.2 Practical contributions to the industry

This study presents concrete recommendations for enhancing GB promotion efforts in China. By analysing the temporal and spatial distribution of GBPs, it offers a comprehensive overview of China's GBP system, highlighting its strengths, weaknesses and regional disparities in implementation. This broader perspective aids central and local authorities, as well as industry stakeholders, in understanding the development trajectory and current landscape of GBPs. Practically, this analysis facilitates more informed and context-specific policy adjustments better aligned with regional conditions, thereby improving policy coherence and effectiveness nationwide.

In terms of stakeholder cooperation, the study identifies critical factors that shape interactions among central and local governments and developers, particularly under conditions of information asymmetry. By uncovering motivations—such as financial incentives, regulatory measures and developer interests—it equips industry practitioners and policymakers with strategies to foster collaboration, minimise conflicts of interest and create more cohesive policy frameworks. This understanding helps establish cooperative dynamics within the GB market and MLG, supporting the widespread adoption of sustainable building practices and providing clear guidance for scaling up GB promotion.

The dual principal-agent model offers a practical framework for designing policy incentives that address information asymmetry in both collusive and non-collusive scenarios. By developing context-sensitive incentives that account for regional disparities and prevent undesirable behaviours (e.g., potential collusion and information asymmetry), this model provides operational tools for achieving high-quality GB promotion. Tailored mechanisms can accommodate different cost structures among developers and dynamically adapt to local socio-economic conditions, ensuring that policies are robust, adaptive and aligned with high standards of GB implementation.

Moreover, empirical validation of the proposed policy models enhances their practical relevance, offering evidence-based insights for refining GB strategies. This data-driven approach not only confirms the theoretical robustness of the incentive mechanisms but also demonstrates their practical viability. Policymakers can thus employ these empirically tested strategies to optimise GBP implementation, ensuring that they are grounded in real-world observations and adaptable to China's MLG structure.

9.5 Limitations and Further Research Directions

While this study provides valuable insights into GB promotion in China through the lens of MLG, there are several limitations that need to be addressed. These limitations highlight potential avenues for further research:

This study's regional analysis of GBPs primarily focuses on the provincial level, categorising policies into three broad regions: eastern, central and western China. Although this approach reveals regional disparities and differences in policy evolution, it does not provide a highly granular understanding of local policy dynamics. The relatively coarse level of analysis limits the ability to identify finer regional nuances, such as variations at the city or municipal level, which could be critical in understanding localised GB adoption patterns. As more cities introduce specific GBPs, future research could adopt a city-level analysis. Such a refined approach would enable a more detailed examination of local policy effectiveness, supporting more precise and tailored recommendations for GB promotion across different urban contexts.

In addition, this study's modelling approach primarily captures the vertical dimension of MLG, focusing on the interactions between central and local governments. While this perspective is useful for understanding hierarchical coordination and policy implementation, it overlooks the complexities of horizontal interactions. In practice, GBP implementation involves not only coordination across different levels of government but also interactions among departments at the same level, as well as between governmental and non-governmental organisations. Future research could incorporate these horizontal dynamics, exploring aspects such as inter-departmental collaboration, competition and coordination with non-governmental actors. A more comprehensive MLG model that includes both vertical and horizontal dimensions would offer a richer understanding of the stakeholder dynamics that shape GBP formulation and implementation.

Moreover, the study currently focuses on static incentive mechanisms, where contracts are designed as one-time arrangements. While this approach provides initial insights, it does not adequately reflect the evolving nature of real-world decision-making, where stakeholders adapt their strategies in response to changing conditions. Developers, for instance, often adjust their approaches based on market shifts, policy changes and new regulatory pressures. To address this limitation, future research could explore dynamic incentive mechanisms that adjust over time, taking into account the adaptive strategies of developers and other stakeholders. Incorporating dynamic contracts would provide a more realistic representation of policy impacts, promoting sustained engagement and compliance throughout different phases of GB promotion. This adaptive approach could better align policy measures with long-term sustainability goals, offering a more flexible and responsive framework for GB promotion.

Appendix A The Supplemental Materials for GBPs

Note: The tables below are the supplemental materials of GBPs in China, which are helpful in showing the research details of different provinces.

Table A.1 Distribution of policy types by province/municipality.

Province/ Municipality	DBPs	FSPs	SBPs	RBPs	TSPs
			Eastern region		
Beijing	10	6	9	1	7
Fujian	22	9	35	27	17
Guangdong	43	15	28	38	12
Hainan	10	2	13	7	3
Hebei	33	11	16	21	18

Jiangsu	19	7	37	16	3
Liaoning	11	1	11	8	6
Shandong	32	18	48	21	1
Shanghai	8	3	8	5	2
Tianjin	8	2	2	4	7
Zhejiang	33	15	25	13	16
Central region					
Anhui	25	16	45	31	6
Henan	13	10	12	9	4
Heilongjiang	21	0	4	12	3
Hubei	29	7	14	38	4

Hunan	14	7	10	10	6
Jilin	9	0	7	9	2
Jiangxi	11	2	3	12	5
Shanxi	11	5	6	7	4
			Western region		
Gansu	14	3	6	5	3
Guangxi	11	1	7	18	15
Guizhou	8	3	13	5	1
Inner Mongolia	12	7	7	4	2
Ningxia	7	2	5	4	2
Qinghai	5	2	5	5	3

Shaanxi	13	4	4	6	1
Sichuan	9	4	4	7	4
Xinjiang	9	7	5	1	0
Yunnan	3	1	0	2	0
Chongqing	16	2	28	15	17
Tibet	1	1	0	1	1

Table A.2 Distribution of policy intensity by province/municipality.

Province/	Eastern region										
Municipality	Beijing	Fujian	Guangdong	Hainan	Hebei	Jiangsu	Liaoning	Shandong	Shanghai	Tianjin	Zhejiang
Stage 1	0	0	0	0	6	0	0	0	0	0	0
Stage 2	10.74	7.33	9.19	7.94	8.63	10.94	11.25	11.85	11.33	8.44	12.23
Stage 3	10.93	9.30	11.49	14.53	11.68	10.20	10.14	9.43	9.36	17.14	13.38
All stages	10.82	8.26	10.46	11.51	10.39	10.48	10.20	10.24	10.27	11.09	12.99

Province/	Central region							Western region			
Municipality	Anhui	Henan	Heilongjiang	Hubei	Hunan	Jilin	Jiangxi	Shanxi	Gansu	Guangxi	Guizhou
Stage 1	0	0	0	0	6	0	0	0	0	0	0
Stage 2	9.15	7.13	7.31	9	9.71	11.7	9.9	11	7.36	6.09	6.8

Stage 3	12.48	10.67	8.70	11.25	11.50	10.74	8.57	12	7.82	7.68	9.8
All stages	10.67	8.46	8.43	10.50	10.85	11.09	8.97	11.70	7.61	7.35	7.3

Province/ Municipality	Tibet	Yunnan	Inner Mongolia	Shaanxi	Sichuan	Xinjiang	Chongqing	Ningxia	Qinghai
Stage 1	0	0	0	0	0	0	0	0	0
Stage 2	0	18	9.94	12.13	8.42	9.57	8.95	9.11	9
Stage 3	14.5	8.33	12.69	9.85	13.41	21.38	9	16.09	9.08
All stages	14.5	13.17	11.31	11.07	11.27	13.86	8.96	12.95	9.05

Appendix B Questionnaire

Survey on Green Building Promotional Policies

Dear Sir/Madam,

Greetings! I am a joint PhD candidate at Hong Kong Polytechnic University and Sichuan University, conducting research on policies for promoting green buildings. I am currently undertaking a related questionnaire survey. This survey seeks your expert opinion on various aspects of green building promotion policies. Your honest responses are greatly appreciated, and all data collected will be kept strictly confidential and used solely for this research project. We assure you that your privacy will be fully protected. Your thoughtful participation is crucial to the success of this study, and we are grateful for your support and cooperation.

Research Background

Please respond to the following items based on your experience and perspectives. Explanations for certain terms are provided in brackets next to the items. Select the option that best reflects your agreement with each statement.

I. Demographic Information

1. Your Gender:

A. Male B. Female

2. Your Age:

A. 30-40 years B. 40-50 years C. 50-60 years D. Over 60 years

3. Your Region:

A. Eastern   B. Central   C. Western

4. Your Occupation:

A. Government or Public Sector   B. Researcher   C. Other

5. Your Education Level:

A. Bachelor's Degree   B. Master's Degree   C. PhD

II. Subjective Attitude Items

1. Incentive mechanisms linked to environmental benefits are effective in motivating local governments to promote green buildings.

A. Strongly Disagree   B. Disagree   C. Neutral   D. Agree   E. Strongly Agree

2. Incentive mechanisms linked to the level of building greenness are effective in encouraging developers to enhance green building quality.

A. Strongly Disagree   B. Disagree   C. Neutral   D. Agree   E. Strongly Agree

3. Reducing fixed payments to local governments while maintaining incentive intensity is effective in promoting green building initiatives, especially when collusion is minimised. (Collusion refers to local governments exaggerating the environmental benefits of green building projects in collusion with enterprises; incentive intensity refers to the profit distribution ratio.)

A. Strongly Disagree   B. Disagree   C. Neutral   D. Agree   E. Strongly Agree

4. Providing higher incentive intensity to local governments with lower implementation costs is effective in promoting green building initiatives.

A. Strongly Disagree   B. Disagree   C. Neutral   D. Agree   E. Strongly Agree

5. Providing higher incentive intensity to low-cost developers is effective in motivating them to improve green building quality.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

6. Increasing the incentive intensity by the government is effective in motivating developers to improve green building quality.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

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III. Matrix Scale Items

1. The central government should initiate specialised inspections for green buildings at an early stage.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

2. The central government should lead the specialised inspections and maintain a high frequency of inspections.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

3. The central government should establish an evaluation system for green building responsibility.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

4. The central government should penalise developers for rent-seeking behaviour.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

5. The central government should hold developers legally accountable for rent-seeking behaviour.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

6. The central government should politically hold local government officials accountable for rent-seeking behaviour.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

7. Local governments have made significant contributions to the promotion of green buildings.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

8. Local governments strictly regulate green building implementation.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

9. Local governments have enacted clear policies to support green building promotion.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

10. Developers incorporate a high proportion of green building projects in their construction activities.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

11. Developers are willing to invest more in green building development.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

12. Developers refrain from obtaining green project certifications through fraudulent means.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

13. The cost for local governments to formulate green building policies is relatively high.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

14. The risks associated with implementing green building policies are high for local governments.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

15. The coordination costs for local governments to implement green building policies are high.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

16. The central government should allocate substantial transfer payments to support local green building policies.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

17. Green building target completion should weigh heavily in the central government’s performance evaluation of local governments.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

18. The central government should impose stringent political accountability on local governments that passively promote green buildings.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

19. The central government should promptly report and rectify areas that fail to meet green building targets.

A. Strongly Disapprove B. Disapprove C. Neutral D. Approve E. Strongly Approve

20. Local governments provide subsidies for green building developers.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

21. Local governments give priority to awarding green building projects.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

22. Developers engaged in green building development receive credit support.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

23. Local governments offer floor area ratio bonuses to green building developers.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

24. Higher mortgage limits are available for purchasing green buildings.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

25. Mortgage rates are lower for green building purchases.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

26. Local governments provide subsidies to green building buyers.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

27. Local governments impose fines on developers for green building violations.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

28. Local governments downgrade or revoke the qualifications of developers who violate green building regulations.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

29. Local governments record green building violations in developers' integrity files.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

30. Consumers support the development of green buildings.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

31. Consumers are highly willing to purchase green buildings.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

32. Consumers are willing to live in green buildings.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

33. The development costs of green building developers in the market are generally low.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

34. Low-cost green building developers are common in the market.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

35. High-cost green building developers are rare in the market.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

36. Green building developers have adopted more advanced green technologies and management measures.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

37. Green building developers have selected more environmentally friendly building materials.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

38. Green building developers are willing to incur higher costs to improve the quality of green buildings.

A. Strongly Disagree B. Disagree C. Neutral D. Agree E. Strongly Agree

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This concludes the questionnaire. Please check if any questions have been missed! Thank you again for your cooperation and support!

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