Pricing the Priceless:

The Financial Cost of Biodiversity Conservation*

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Abstract

Biodiversity loss as a global concern requires dramatic shifts in conservation efforts that carry substantial costs. We offer an initial investigation into how the financial market prices such conservation costs, exploiting the "Green Shield Action" (GSA) --- a regulatory change aimed at preserving biodiversity in national nature reserves in China --- as an exogenous shock to local public financing. We document that GSA, while improving biodiversity, augments the yields of municipal corporate bonds by around 25 basis points. The effects are more pronounced for bonds with shorter maturities and for local governments in weak fiscal positions. The increased cost of public capital can be largely attributed to transition pressure resulting from pre-existing economic activities within reserves and the growth in local public spending on biodiversity following the reform. Investors show little consideration towards endeavors counteracting biodiversity loss beyond financial payoffs. Our findings also provide insights concerning investor education and policy interventions for addressing the financing gap for biodiversity conservation.

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1. Introduction

The biodiversity crisis casts an imminent shadow over the intricate nexus between nature and the global economy (Flammer *et al.* 2023). Without dramatic shifts from current practices, up to 50% of all species may face extinction in the next 2-3 decades (Deutz *et al.* 2020), which calls for a unified effort in biodiversity conservation. Although prior studies have evaluated direct economic costs of this transition (IPBES 2019; Deutz *et al.* 2020) and the equity pricing of biodiversity risks (Garel *et al.* 2023; Giglio *et al.* 2023), the financing of biodiversity transition and its implications for the financial markets remain largely unexplored (Karolyi & Tobin-de la Puente 2023; Starks 2023).

We bridge this gap in the literature by analyzing a major policy shift in China for biodiversity conservation, the Green Shield Action (GSA)---a large regulatory shock aimed at reinforcing the safeguarding of national nature reserves (NNRs). GSA, while improving biodiversity, augments the public cost of capital by 25 basis points, an effect more pronounced for bonds with shorter maturities and for local governments in weak fiscal positions. The increase can be largely attributed to transition pressure resulting from pre-existing economic activities within reserves and the growth in local public spending on biodiversity following the reform, even though local governments did not raise additional capital. We show that investors show little consideration towards endeavors counteracting biodiversity loss beyond financial payoffs. We further quantify the aggregate cost on public financing of biodiversity transitions and discuss the heterogeneity in the tradeoffs between economic sustainability and biodiversity sustainability, with implications for future policy interventions and funding allocations.

China is blessed with a wealth of biodiversity. The country's nature reserves, especially those at the national level, are legally designated to play a pivotal role in preserving its biodiversity. Nevertheless, some reserves failed to fulfill their protective responsibilities for a prolonged period.[2] In response, the Chinese central government launched the Green Shield Action in July 2017, targeting violations within NNRs such as mining, tourism, and hydropower. In practice, the central government has conducted rigorous investigations and exerted substantial rectification pressure on local authorities. Consequently, GSA has led to a notable increase in local government efforts on biodiversity conservation and the management of NNRs, marking a milestone in China's commitment to biodiversity conservation.[3]

[2] A prime example is the Qilian Mountain National Nature Reserve in Gansu Province, where rampant illegal exploration and mining activities have caused significant damage to the reserve for an extended period (see details in Section 2.1).

[3] For example, after GSA, the Management Committee of the Chongqing Jinyun Mountain National Nature Reserve executed environmental remediation and ecological restoration projects, and developed a management plan for the NNR via government procurements. (see details in Appendix B1).

We focus on the impact of GSA on the pricing of municipal corporate bonds (MCBs). Our setting offers several advantages. First, GSA is a unified, top-down initiative explicitly targeting NNRs, leaving little discretion for local governments in terms of implementation (Wang et al., 2023). The conservation and funding efforts for preserving biodiversity in NNRs largely fall on the shoulders of local governments. This has led to substantial increases in financial pressure for municipalities containing NNRs after the introduction of the GSA. Second, unlike corporations, municipalities cannot change their locations to avoid transition and conservation costs. Thus, MCB investors must account for such local risk when valuing municipal bonds.

Our empirical analysis relies on several datasets. First, we use data on issuance and trade information on all MCBs in China from January 2013 to June 2022. Second, we manually construct a new dataset containing the geographical location of all NNRs in China. This enables us to identify municipalities whose territory encompasses these natural reserves. To evaluate the impact of GSA on local conservation efforts, we also use satellite remote sensing data, and information sourced from government procurement documents, newspaper articles, and bird observation records. These additional datasets provide a multifaceted perspective for ascertaining the mechanisms through which GSA influences public financing costs.

We employ a standard difference-in-differences (DID) strategy, comparing changes in the yield spreads of MCBs for cities with at least one NNR (NNR municipalities) relative to those without NNRs (non-NNR municipalities) before vs. after the launch of GSA. We select the third quarter of 2017, the initiation time of GSA, as the beginning of the treatment period. We document that, compared to non-NNR municipalities, NNR municipalities experience a 25 basis points larger increase in their yield spreads following the introduction of GSA. This corresponds to 18% of the in-sample standard deviation (136 basis points). We also extend the specification to more flexible measures of treatment intensity (i.e., the number and area of NNRs), finding consistent pricing effects. The results are also robust to alternative bond spread measures and data frequency.

A central challenge with our identification strategy is whether the documented differences in bond yields between treatment and control groups around the introduction of GSA are driven by expected local public financing costs or other confounding factors. A comparison of municipality characteristics shows that municipalities with and without NNRs are similar across a large set of observables in the pre-GSA period. Our estimating equation includes controls for bond-, issuer-, and city-level characteristics, and our main coefficients are stable when including such controls. Finally, we show that municipalities with and without NNRs display similar

trends in yield spreads in the period before the introduction of GSA, lending support to our identification assumptions.

To explain how GSA prompted an increase in the risk premium demanded by MCB investors, we underscore the market's apprehensions regarding biodiversity transition costs and provide multiple pieces of supporting evidence. First, we investigate whether the transition pressure can explain the increased MCB spreads. We focus on the (ex-ante) extent of human economic activities within the NNRs, as it reflects the expected effort level that local governments have to undertake to comply with the criteria of GSA (i.e., eliminating illegal activities inside NNRs and recovering the corresponding damaged local biodiversity). Utilizing remote sensing data on developed land and night-time luminosity, we show that a higher presence of human economic activities within NNRs before GSA is associated with a more pronounced pricing effect.

Second, we explore biodiversity-related public spending through changes in government procurement contracts, a critical and observable component of government expenditures. We classify the contracts pertaining to NNRs using a standard textual analysis approach. The empirical results reveal that after the implementation of GSA, NNR municipalities demonstrated a more pronounced growth in amounts of such contracts. These results directly shed light on the potential connection between biodiversity transition and the observable escalation in MCB spreads from the perspective of the real costs incurred.

Third, we study the overall changes in the local public creditworthiness following GSA. We find a decline in the fiscal surplus of NNR municipalities compared with non-NNR municipalities. Moreover, the impact of GSA on MCB spreads is more significant when the local public burden is heavy and when the maturity of MCBs is short. We consider whether the observed pricing effects could be attributed to an escalated public financing demand. To fund the growing spending on biodiversity, local governments may not only reorganize internal resources, but also seek more external financing. This surge in the demand side of local public financing could theoretically exert upward pressure on interest rates as the government competes for capital. In addition, there is the concern that the heightened political risk, stemming from the part of holding officials accountable in the reform, could also influence MCB yields. However, we find no supportive empirical evidence for these two channels. Borrowing activities of local governments and the turnover of local officials remain stable around GSA. Collectively, these findings offer compelling evidence in support of the pricing impact of the deteriorating local public credit conditions.

In addition to examining investor decisions related to transition costs in GSA, we

also study investors' potential non-pecuniary preference for biodiversity ("Values" in Starks, 2023). Specifically, if there are a considerable amount of impact investors who indeed care about biodiversity but are informed of the actual biological conditions within NNRs, GSA may remind them of the poor management there in the early stages. This information effect may trigger investors to impose an overdue punishment on the financing securities on responsible authorities. If this mechanism holds, we expect that cities with higher information asymmetry on NNRs experienced a larger increase in MCB spreads. We compare NNR municipalities to different levels of newspaper coverage of related NNRs but find insignificant heterogeneity effects.

Investors' non-pecuniary preference could also favor biodiversity enrichment from the GSA. By analyzing data on bird species recorded by both birdwatching enthusiasts and research observation stations, we consistently find that GSA has led to an increase in the diversity of local bird species, which serves as a proxy for biodiversity. However, NNR municipalities with greater improvement in biodiversity did not exhibit significantly less heightened MCB spreads. These findings highlight the positive impact that GSA can have on promoting and sustaining biodiversity, and further contrast the adverse influence of escalating financing costs on the biodiversity transition. A lack of alignment between biodiversity benefits and investors' valuation may hinder biodiversity conservation in the long run.

To quantify the aggregate effect of the pricing of biodiversity transition, we make a back-of-envelope assessment of the additional financing costs resulting from GSA by comparing counterfactual payments inferred from DID estimates. Our conservative calculation is based on the outstanding debts of Local Government Financing Vehicles (LGFVs) with MCBs[4] from 2013 to 2021. Given the estimated global annual financial gap of 711 billion dollars since 2019 by Deutz *et al.* (2020), China needs to spend 45.5 billion dollars per year on protecting biodiversity according to its proportion of species. Then the extra financing costs brought by GSA accounted for 12.73%, 19.82%, and 28.70% of the total direct costs ($45.5 billion) in 2019, 2020, and 2021, respectively. Our findings also inform about the heterogeneity in efficacy in policy interventions and how to allocate resources from the central government to best alleviate local financial debacles. Importantly, policy-makers need to recognize and balance the tradeoff between fiscal sustainability and biodiversity sustainability.

Our paper contributes to studies assessing the benefits and costs of natural capital and biodiversity protection. The seminal contribution by Weitzman (1992, 1993, 1998) measure the "value of diversity." Heal (2001) provides an overview of biodiversity's services, and Brock and Xepapadeas (2003) integrate ecological and economic systems

[4] In practice, LGFVs are direct issuers of MCBs (see details in Section 2.3)

through a framework for valuing biodiversity. Recent studies indicate that, as an example of natural capital, wetlands can reduce flood risk (Rizzi 2022; Taylor & Druckenmiller 2022). However, the private cost of protecting biodiversity could be substantial (Watson *et al.* 2014; Adams *et al.* 2019), and the benefits might be minimal (Simpson *et al.* 1996), making it difficult for the private sector to act in biodiversity conservation (Flammer *et al.* 2023). Meanwhile, existing papers have evaluated the economic costs of preserving biodiversity from many angles; we advance the literature by exploring the neglected public financing costs in biodiversity transitions. Our work thus complements the recent studies on the correlation between biodiversity loss risk and the financial market (Garel *et al.* 2023; Giglio *et al.* 2023), and responds to the calls for research on "biodiversity finance" (Karolyi & Tobin-de la Puente 2023) and "biodiversity risk" (Starks 2023).

Our paper also contributes to the financial implications of environmental regulation by extending existing literature to include biodiversity protection within this broader context. In recent years, climate regulation has emerged as a prominent environmental theme and its financial implications, especially its negative impact on borrowing activities, have attracted considerable attention (e.g., Seltzer *et al.,* 2020, Jha *et al.,* 2020, and Dang *et al.,* 2022). In addition, Ilhan *et al.* (2021) emphasize the potential risks associated with stranded assets due to changes in environmental policy, which also manifests in banking activities (Delis *et al.* 2018). Hong *et al.* (2023) study the risk of stranded assets in the bond market, highlighting the transition costs that firms encounter in response to Renewable Portfolio Standards. While numerous private entities have dedicated efforts towards climate change, there remains a notable gap in action regarding biodiversity (Karolyi & Tobin-de la Puente 2023). Our paper contributes to the literature by establishing a causal link between biodiversity regulation and the public cost of capital, while existing studies predominantly focus on transition risks within corporations. Moreover, our work provides insights into the land use policy and resource allocation concerning biodiversity, whose risks differ from climate risk that emphasizes more on carbon emission and pollution (Garel *et al.,* 2023).

Third, our paper contributes to the literature on the determinants of local public financing costs. Prior works focus on the U.S. municipal bond market. Factors discussed include state fiscal policy (Poterba & Rueben 2001; Gao *et al.* 2019; Babina *et al.* 2021), municipal governance quality (Butler *et al.* 2009; Gao *et al.* 2020), climate risk (Painter 2020; Goldsmith-Pinkham *et al.* 2022; Jerch *et al.* 2023), demographic features (Dougal *et al.* 2019; Butler & Yi 2022), public health issues (Cornaggia *et al.* 2022b; Gao *et al.* 2022; Tran & Uzmanoglu 2022; Cheng *et al.* 2023), pension

underfunding (Novy-Marx & Rauh 2012), the credit rating (Cornaggia *et al.* 2018), and other market frictions (Butler 2008; Schultz 2012; Chalmers *et al.* 2021; Cornaggia *et al.* 2022a). Turning to China, MCB is deemed to be the only asset with market prices that can capture the funding costs of Chinese city and county government, inextricably tied to regional development (Liu *et al.* 2017; Ang *et al.* 2018). Nevertheless, the impact of policies promoting economic transition (e.g., industry restructuring, going green) on the government's own borrowing has received limited attention overall. Jha *et al.* (2020) present an increase in municipal bond yields after the Clean Air Act. In a causal context, our work implies that while government intervention may address the problems of externality inherent in the sustainability transition, there exist other frictions that cause social deadweight loss. In the absence of mechanisms within financial markets to support long-run social benefits, policies aimed at sustainability counterintuitively elevate the cost of public capital.

The rest of the paper is organized as follows. Section 2 presents background information about the nature reserves in China, GSA, and the MCB. Section 3 describes the data. Section 4 reports the identification strategy and empirical findings. Section 5 explores underlying economic channels for the increased cost of public capital. Section 6 considers the biodiversity benefits associated with the reform and investors' non-pecuniary values. Section 7 quantifies the aggregate cost and discusses policy implications. Section 8 concludes.

2. Institutional Background

2.1 Nature Reserves in China

With vast expanses of diverse terrain and climate zones and a recorded number of known species reaching 138,293 --- a remarkable 6.4% of the total worldwide tally of 2,161,755 (as of 2022, including 687 mammal species, 10.4% of the recorded global mammal total of 6,596 and 46,725 plant species, 11% of the recorded global plant total of 424,335), China is among the most biologically diverse countries.[5] For example, China ranks third in the world in terms of its number of higher plant species, surpassed only by Brazil and Colombia. This wealth of biodiversity is a testament to China's natural heritage and underscores its vital importance to the global ecosystem.

To protect the natural capitals, China has designated an extensive network of nature reserves --- land, inland waters, or seas containing representative natural ecosystems, hotspots for rare and endangered wild species, or natural relics with distinctive significance.[6] Among these reserves, National Nature Reserves (NNRs)

[5] See in http://www.sp2000.org.cn/CoLChina and https://www.iucnredlist.org/resources/summary-statistics.
[6] Specifically, our definitions of the nature reserve are all based on the Regulation of the People's Republic of

hold the highest rank with the most extensive regulatory oversight and strictest legal provisions compared with other provincial, municipal, and county nature reserves. Correspondingly, regulations stipulate that only reserves "holding typical significance domestically and internationally, exerting remarkable international scientific influence, or possessing extraordinary research value" can be designated NNRs.

The designation of NNRs is solely based on the biological condition of natural resources, without considering local economic and fiscal situation.[7] According to regulations, the local government should first submit a formal application to the administrative authority of NNRs under the State Council. Then the central review committee for NNRs is responsible for the evaluation process. After receiving a report on the candidate reserve's biological situation, committee members vote. For an NNR to be eligible for State Council approval, it must receive a two-thirds majority vote from the committee. The representativeness, fragility, diversity, rarity, endangered status, importance, and scientific value of the reserve's natural resources carry significant weights in the evaluation. The members of the review committee are predominantly experts in the field of natural sciences, with no representation from the economic or financial domains. Figure 1 illustrates the development process of nature reserves in China.[8] It is evident that the number and size of NNRs have virtually slowed down after 2006. Given that the municipal corporate bonds (MCBs) market began to develop rapidly after 2008 (see Section 2.3), our setting can address the concern that economic development fueled by MCBs may have impacted the establishment of NNRs.

Following the establishment, the local governments are responsible for managing, supervising, and conserving NNRs within their jurisdictions. Each NNR is typically governed by a dedicated management committee that handles its routine operations. This committee functions as an administrative entity under the local government's authority, and is financed by local government allocations[9]. In addition to local financial support, NNRs also receive funding from the central government. Nevertheless, this central funding is not adequate. For example, Jianbo Sun, a delegate

China on Nature Reserves. Legally, the establishment and management of nature reserves within the territory of the People's Republic of China and other sea areas under the jurisdiction of the People's Republic of China shall be governed by this regulation. Consequently, in a practical view, nature reserves are specifically for biodiversity preservation in China.

[7] See more details in: https://www.mee.gov.cn/stbh/zrbhq/gjjzrbhqps/201605/t20160522_342427.shtml

[8] As illustrated in Figure 1, the history of reserves dates back to the 1950s, with the establishment of the first nature reserve, the Dinghushan Nature Reserve. Following the economic reform and liberalization of 1978, the number of nature reserves underwent substantial growth. Then towards the end of the 20th century, China experienced several environmental crises, including the drying out of the Yellow River in 1997, the flooding of the Yangtze River in 1998, and the sandstorm that swept Beijing in 2000. These disasters necessitated a reconsideration of the connection between economic growth and ecology, culminating in a further significant expansion of nature reserves during 1997-2010. Subsequently, the rate of growth slowed considerably. By 2017, the number of nature reserves had reached around 2,700, covering over 140 million hectares.

[9] See Appendix B2 for more details regarding the institutional structure arrangement of NNRs.

of the 13th National People's Congress, presented a proposal highlighting that the central government's annual funding for all NNRs totals only 600 million yuan. This breaks down to an average of just 1.26 million yuan for each reserve. Given this limited central funding, local governments bear the brunt of the financial responsibility for maintaining NNRs.[10]

Although a large number of nature reserves were established, their actual effectiveness in protecting biodiversity fell short of expectations in the initial phase. Local officials mostly prioritized economic development over environmental issues over the several decades before our sample period (Guan *et al.* 2010; Liu 2010), resulting in the deterioration of numerous reserves. A prime example is the Qilian Mountain National Nature Reserve in Gansu Province, where rampant improper exploration and mining activities caused substantial damage to local vegetation, soil erosion, and surface subsidence for an extended period. For instance. 14 mining and exploration rights granted within this area were found unauthorized, with 3 instances within the core zones. In addition, over 30 mining projects were concealed, and over 40 hydropower facilities were constructed illegally. This "Qilian Mountain Incident" precipitated the special supervision and inspection actions led by several national departments, namely the Green Shield Action (GSA).[11]

2.2 Green Shield Action

Launched in July 2017, GSA covers all NNRs in China for the first time and marks a full-scale effort for biodiversity conservation in NNRs. Its initial round identified over 20,800 potential issues and concerns related to nature reserves, resulting in the closure and ban of over 2,460 enterprises and the demolition of over 5.9 million square meters of constructed facilities. Meanwhile, more than 1,100 local government officials were held accountable, and several local regulations inconsistent with higher-level law were modified. Overall, GSA marks a monumental stride in China's endeavor to regulate and supervise NNRs, and attests to policymakers' resolute commitment to improving its biodiversity conservation.

Specifically, GSA utilized various technologies to monitor and inspect, including high-resolution remote sensing, geographic information systems, global positioning systems and big data to identify illegal activities. The central government also called for lists of remote sensing problems so that various departments can promptly provide relevant information to the central inspection team or the local supervision authority.

[10] See Appendix B3 for more details regarding funds sources for nature reserves. The

[11] The central government conducted a special investigation into the Qilian Mountain National Nature Reserve, verified the ecological damage, held responsible leaders of local governments and state-owned enterprises accountable, and made a public announcement (see http://www.gov.cn/xinwen/2017-07/20/content_5212107.htm).

Each municipality was required to develop and implement work plans in accordance with the GSA criteria, including self-inspections of each reserve, spot-checking by working teams at the province level, and creating management accounts for illegal activities. By utilizing these approaches, the central government placed significant political incentives on local officials, in order to ensure that problematic leads could be thoroughly investigated and that illicit activities could be seriously addressed.[12]

After the central inspection, GSA implementation encountered local resistance. For one, the reserves had long suffered from a lack of resource allocation. Without the central funding, some NNRs were severely understaffed.Moreover, prior to the designation of an area as a NNR, there were already a large number of residents living within these regions. Relocating these residents and demolishing their structures had proven to be extremely challenging. Finally, local governments also need to undertake ecological restoration projects within the reserves and allocate substantial funds to enhance the supervision of these areas and improve their operations. All of these factors entail significant costs.[13]

Based on the annals of GSA, a representative case is the relocation of Jinyun Mountain Nature Reserve in Chongqing Province. The reserve was strictly off-limits to all individuals and entities, with only personnel engaged in scientific research and observation activities being legally allowed to enter a buffer zone. However, with nearly 9,000 residents living within the reserves, local authorities faced an immense burden in meeting GSA's requirement to safely evacuate the area. Specifically, the Beibei District Government, which oversees the Jinyun Mountain Reserve mainly, invested over 440 million yuan in the relocation effort, despite its fiscal revenue being a mere 3 billion yuan for that year. Additionally, GSA stipulates that Chongqing Government should demolish all illegal buildings within the reserve, including housing, agricultural tourism facilities, hotels, and horse farms. Such requirements cannot be immediately solved and further compound the already substantial economic costs.[14]

Following the GSA introduction in late 2017, the central government continued the effort in subsequent years. The objectives of the following years entail reinforcing the biodiversity transition, verifying the implementation of rectification requirements, scrutinizing new violations of laws in nature reserves, and supervising the fulfillment of management responsibilities of relevant departments. These efforts indeed promoted the restoration of the local ecology (e.g., see the changes in the land cover of the Qilian Mountain National Nature Reserve shown in Figure A1). Meanwhile, by perpetuating these actions annually, the central government solidifies overall expectations of their

[12] See Appendix B4 for further details regarding the political incentives faced by local officials.
[13] See Appendix B5 for further details regarding the challenges encountered during GSA.
[14] See Appendix B6 for further details regarding the initiatives undertaken by the Chongqing government.

unwavering resolve to protect biodiversity and nature reserves, thus shaping the financial market's perception of the substantial transition costs associated with biodiversity conservation.

2.3 Municipal Corporate Bonds

In the 1990s, the tax-sharing reform in China substantially reduced the proportion of tax revenue allocated to local governments. Meanwhile, the 1994 Budget Law prohibited local governments from directly engaging in any form of debt financing. For municipalities, one way to balance the growing demand for public investments and insufficient fiscal resources is to establish local government financing vehicles (LGFVs), special-purpose state-owned enterprises. LGFVs primarily undertake the supply of local common goods (e.g., public infrastructure) and are not contained in the local government's balance sheet. To finance public projects with long cycles and low direct earnings, LGFVs can borrow from financial institutions and issue bonds, backed by local-authority-appropriated land, subsidies, and other implicit guarantees.

Due to regulatory restrictions, LGFVs grew slowly in the early stage until the Chinese central government launched a large stimulus package in November 2008 in response to the global financial crisis. The fiscal part of this package is commonly known as the 4-trillion-RMB plan, which mainly consists of public infrastructure and social welfare projects. Financing-wise, more than two-thirds of planned investments (2.82 trillion RMB) were expected to be funded by local governments. To facilitate these programs, the central government introduced a series of credit expansion (Cong *et al.* 2019) and financial deregulation policies (Bai *et al.* 2016), encouraging local governments to raise funds through LGFVs[15]. Subsequently, both the number and total liability of LGFVs experienced a significant disorderly surge[16], which raised concerns about the default risks of municipalities[17]. Then Beijing reverted its aggressive credit policy back to normal in 2010, making LGFVs resort more to bond financing when facing rollover pressure from bank debt coming due around 2012 (Chen *et al.* 2020).

The bonds issued by LGFVs are generally referred to as municipal corporate bonds (MCBs, see, e.g., Chen *et al.* 2020 and Gao *et al.*, 2021), where "corporate" reflects the

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[15] Financial deregulation policies include: (1) *Guidelines on Further Strengthening the Adjustment of Credit Structure to Promote Steady and Rapid Development of Economy,* released by the China Banking Regulatory Commission (CBRC) in March 2009, (see http://www.gov.cn/gongbao/content/2009/content_1336375.htm). (2) the *Notice on Accelerating the Implementation of Local Supporting Funds for Central Government Investment Projects to expand Domestic Demand,* released by the Ministry of Finance of the People's Republic of China (PRC) in October 2009 (see http://www.gov.cn/zwgk/2009-10/13/content_1437713.htm).

[16] Fan *et al.* (2022) show that in 2009, the total value of LGFV bonds increased by 217%, and bank loans to LGFVs surged by 93%. Besides, the debt raised by LGFVs represented more than 70% of the total debt of local governments, and it surged from 1.7 trillion yuan in 2007 to 6.6 trillion yuan in 2010 and doubled again in 2014.

[17] Gao *et al.* (2021) show that some LGFVs fell to an actual default on loans, suggesting that municipalities indeed have considerable credit risk that could be priced in MCB yields, consistent with Ang *et al.* (2018).

fact that LGFVs have the same legal status as other regular corporations nominally, and "municipal" indicates the exclusive implicit guarantee from the local government.[18] In 2015, the new Budget Law became effective, allowing provincial governments to issue municipal bonds directly. However, MCBs are still the dominant form of local public financing in our setting. First, the overwhelming majority of city governments are not authorized to issue municipal bonds on their own, and the intra-provincial distribution of proceeds is also not publicly disclosed.[19] In contrast, the vast majority of MCB issuers are LGFVs owned by local governments below the province level.[20] As displayed in Figure 2, every province in China's mainland has multiple NNRs, but a city may not necessarily own one. Therefore, MCBs are better than municipal bonds in matching the cross-sectional variations of GSA.

Second, the market still holds the faith in municipalities' implicit guarantee for LGFVs and thereby price credit risk of local governments when investing MCBs after 2015 (Liu *et al.* 2017). In general, MCBs' credit rating reports typically consider local governments' fiscal conditions at first, which is rarely seen among other issuers. For example, in Moody's *Local Government Financing Vehicles in China Methodology*, "government support" is set as the primary evaluation factor of MCB rating.[21] The rationale behind this is that since cities do not have discretion on issuing municipal bonds directly, their LGFVs are still mainly engaged in non-self-supporting public utilities and rely on recurring financial support from owner governments. In practice, governments at different levels have repeatedly defused the debt repayment crisis of LGFVs.[22] There have been no real default on MCBs so far.[23] All the facts suggest that the price of MCB can incorporate market views on local public financing cost during our sample period.

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[18] MCB is "cheng-tou-zhai" in Chinese, which means "city investment bonds." It is synonymous with some other translations, such as "local government bonds" (Huang *et al.*, 2020), "Chengtou bonds" (Ang *et al.,* 2018), and "urban construction and investment bonds" (Liu *et al.,* 2017), and "LGFV bonds" (Fan *et al.*, 2022).

[19] According to regulatory requirements, only Dalian, Qingdao, Ningbo, Xiamen, and Shenzhen have the right to issue municipal bonds independently among the hundreds of prefecture-level cities.

[20] In our sample, bonds issued by LGFVs owned by provincial governments only account for approximately 10% of the total MCBs from 2013 to 2022.

[21] See https://ratings.moodys.com/api/rmc-documents/386644 (This methodology was first published on July 29, 2020, and updated on April 12, 2022).

[22] A representative case in 2022 is the "Zunyi Debt Event." Zunyi City is the second largest prefecture-level city in Guizhou Province. Its largest LGFV, Zunyi Bridge and Road Engineering Co., Ltd. (ZBRE), had faced a debt repayment crisis since 2019. On June 23, 2022, the Zunyi City Government announced the establishment of the Zunyi Financial Work Leading Group, responsible for "coordinating debt extension, restructuring, and interest rate reduction for various market entities." On July 7, 2022, the Guizhou Province Government held a conversazione for financial institutions, expressing support for resolving debt risks through various means. On December 30, 2022, the ZBRE introduced the *Notice on Promoting Loan Restructuring*, which put an end to the long-standing debt problem and caused a stir in the market. According to this notice, the ZBRE restructured all of its 15.594 billion RMB bank loans, extending them uniformly for 20 years, with only interest payments in the first ten years and principal repayment in installments in the second 10 years.

[23] In contrast, some private-owned and non-LGFV state-owned bond issuers have defaulted (Geng & Pan 2019).

3. Data Description

3.1 National Nature Reserves

We collect the list of nature reserves, along with zoning images of NNRs, from the Ministry of Ecology and Environment of the People's Republic of China (PRC). By aligning these zoning images of NNRs with the standard administrative map of China, we construct a dataset that includes information on the locations, borders, inception dates, and tier classifications of NNRs. This dataset enables us to calculate some fundamental attributes of NNRs (e.g., land area) at both reserve and administration levels. Furthermore, we can construct novel metrics (e.g., human economic activities within NNRs) after merging the data with other geographical datasets.

In our baseline model, we utilize a binary variable to indicate the presence of an NNR within a given city. Cities geographically containing an NNR are assigned to the treatment group (i.e., NNR municipalities), while the others are assigned to the control group (i.e., non-NNR municipalities).[24] One concern about identifying the treatment effect of GSA is that there might be considerable disparities between NNR and non-NNR municipalities in economic development. In this regard, it is imperative to reiterate the predetermined status of NNRs in our regression sample. Furthermore, as introduced in Section 2.1, while local governments were commonly willing to apply for NNRs before GSA, the establishment of NNRs is determined solely by the central government, based on the biodiversity value of the area, without considering local economy or public debt.

To further mitigate the concern, we collect various city-level economic data from local Bureaus of Statistics in China. Upon merging these data with our NNR datasets, we average the main economic variables of each municipalities from 2013 to 2016. Table A1 presents a comparison of these covariates between NNR and non-NNR municipalities, revealing that the treatment and the control groups are not systematically different in most dimensions before GSA. In addition, we include several fixed effects and control variables in our formal empirical analysis to address the concern discussed above. Moreover, thanks to the comprehensive list of all nature reserves provided by the Ministry of Ecology and Environment, we can also investigate, using variations in locations of nature reserves with levels below the national level, whether the presence of a nature reserve is confounded with economic determinants of MCB spreads.

[24] In 2017 and 2018, China introduced 29 new NNRs, which were upgraded from provincial nature reserves (No additional NNRs have been added since 2019). These new NNRs account for only 6% (29/475) of the total number of existing NNRs and encompass 22 cities. Although new NNRs have also been under the supervision of GSA since their establishment, we are still concerned about the potential selection bias associated with the presence of these NNRs. To ensure the validity of our empirical identification, we exclude all 22 cities where the number of NNRs changed after GSA from our sample.

3.2 Data on Municipal Corporate Bonds

We obtain municipal corporate bond data from Wind Information Co. (WIND), the leading financial data vendor in China.[25] WIND provides data on: (1) Issuing yield and attributes of each MCB, including issuing price, issuing yield, issuance date, maturity date, issuing amount, bond type, interest type, credit rating at issuance, state of guarantee, and option clause. (2) Daily transaction information of each MCB, including trading price, trading yield, trading date, trading volume, trading site, residual maturity, and credit rating on the trading day. (3) Information of each MCB issuer, including location and industry. In addition, LGFVs with outstanding MCBs are required to disclose financial reports publicly on a regular basis, including assets, liabilities, revenues, and profits. (4) Daily yield curve of national bonds and bonds issued by the Chinese Development Bank (CDB).

We study MCB yields around GSA at the quarterly frequency using the last daily transaction price of the quarter for each MCB.[26] To proxy for the risk premiums that investors demand for investing in bonds, we use the CDB bond as the reference and calculate MCB spreads as the difference between the MCB yield and CDB yield on the same day and of the same maturity (Geng & Pan 2019).[27] Moreover, we collect the yields of national bonds for robustness checks.

3.3 Sample and Summary Statistics

Our sample covers the time period from January 1, 2013, to June 30, 2022.[28] Table 1 reports the descriptive statistics for the main variables used in our analysis. Besides MCB spread and relevant indicators of GSA described above, there are other bond-, issuer- and city-level variables. Bond characteristics include the logarithm of the issuing amount, residual maturity, bond rating, issuer rating, and whether the bond is option embedded, secured, and traded on the exchange market at trade. Issuer features

[25] We select WIND as our primary data source, as it is the most widely used MCB database in China during our sample period. Our sample completely follows WIND's own classification.

[26] WIND reports historical transaction information in the daily frequency, with price-related metrics weighted by the volume of each trade to the day level. In addition, "trading day" used in this paper refers to the day on which a real transaction took place on the corresponding bond, rather than the day on which investors can trade but not.

[27] The CDB is China's largest development-oriented financial institution with a safe degree of creditworthiness (Gao *et al.* 2021), directly supervised by the central government. Besides, the same as credit bonds including MCB, CDB bonds are not tax-exempt and more comparable to MCBs, making CDB yield a good proxy for the risk-free rate in the context of our study.

[28] As explained by Chen *et al.* (2020), the MCB market was relatively underdeveloped before 2012. Another vital fact is that since the 18th National Congress of the communist party of China (CPC) at the end of 2012, China overall has experienced a new stable political cycle in our sample period without the turnover of the general secretary of the CPC. In addition, we restrict the bond-quarter sample to MCBs issued by city- and county-level LGFVs with fixed interest rates and residual maturity above one year. We also exclude MCBs in the form of private placement notes, convertible bonds, exchangeable bonds, and asset-backed securities, due to their non-standard structure, limited market size, or opaque information disclosure.

include the logarithm of total assets, leverage ratio, and return on assets (ROA) in the year before the bond trading day. City features include the logarithm of GDP and the logarithm of the population in the year before the bond trading day. Details of all these variable definitions are presented in the Table A10. To prevent potential estimation error caused by outliers, we winsorize the MCB spreads, as well as issuer- and city-level continuous variables, at lower 0.5% and upper 99.5% of the baseline sample.

Table 1 shows that about 51% of MCB observations are from NNR municipalities, with about 63% of the observations occurring after GSA, which is consistent with the fact that NNR municipalities account for more than half the cities and the MCB bond market has grown over time. For bond characteristics, unlike the U.S. market, entities in China issue credit bonds with shorter maturity, and has both exchange and interbank (over-the-counter) markets, with the latter dominant. Our sample accords with these facts, for they have an average bond residual maturity of 3.83 years in our sample and were less traded on the exchange market. For credit ratings, we convert letter grades into numerical numbers by assigning 1 to AAA, 2 to AA+, 3 to AA, and so on. The average bond rating and issuer rating are all below 3, which is higher than non-MCB corporate bonds analyzed by Ding *et al.* (2022) and Geng and Pan (2019), reflecting the attribute of "municipal" for MCBs.

Figure 3 illustrates the unconditional dynamic of the average MCB spreads over time. The gap between financing costs of NNR and non-NNR municipalities exhibits no substantial disparities in the pre-GSA period, while the former group surged much more in MCB spreads following GSA. These preliminary observations reveal that MCB investors require a higher risk premium in municipalities with enhanced pressure from biodiversity conservation in NNRs.

4. Empirical Strategy and Findings

4.1 Empirical Strategy

Our empirical strategy follows the standard DID approach, comparing the relative changes in the MCB spreads in NNR municipalities and non-NNR municipalities. The model specification takes the following form:

$$Spread_{bict} = \beta NNR_c \times Post_t + \delta_i + \lambda_t + X_{bict} + \varepsilon_{bict} \quad (1)$$

where b indexes bonds, i indexes issuers, c indexes cities, and t indexes year-quarters. The dependent variable, denoted $Spread_{bict}$, is the spread of bond b issued by issuer i, located in city c, and traded in year-quarter t. For the explanatory variables, NNR_c is a dummy variable that equals one if a city geographically intersects with an NNR and zero otherwise. $Post_t$ is a dummy variable that equals one for the time

following GSA (i.e., from the third quarter of 2017 to the second quarter of 2022). The model also contains the issuer and year-quarter fixed effects, δ_t and λ_t. X_{bict} donates control variables described in Section 3.3. The coefficient of interest in the equation is β, the estimated impact of GSA on MCB spreads.

Before discussing the baseline estimates, we check the assumption of parallel trend. We adopt a fully flexible time-by-time estimating equation that takes the following form:

$$Spread_{bict} = \sum_t \beta_t NNR_c \times Time_t + \delta_i + \lambda_t + X_{bict} + \varepsilon_{bict} \quad (2)$$

where all variables are defined as in Equation (1). The only difference from Equation (1) is that in Equation (2), we interact NNR_c with each year-quarter fixed effect, rather than a post-shock indicator. The estimated vectors of β_t reveal the differences between the treatment and control groups during each time. We expect the estimated β_t to be constant over time before GSA took effect.

Figure 4 plots the estimates of Equation (2) and their 95% confidence intervals. A clear pattern emerges. The conditional difference between the treatment and control groups remained insignificant over time and small in magnitude before GSA. This implies that MCB spreads did not exhibit a disparity before the shock, which is consistent with the parallel trend assumption. As GSA advanced, NNRs became the burden of the local governments, exerting an increase effect on public financing costs. Intriguingly, the relative MCB spreads, did not exhibit an immediate significant rise in Figure 4. Two plausible factors may explain the delay. First, after the central government completed inspections of NNRs from the end of 2017 to the beginning of 2018, it took some time for local governments to implement and promote the central government's orders. There was also a lag in the information sources through which investors can access real inputs of local authorities in GSA (e.g., annual work reports of local governments). Second, local officials and investors might be uncertain regarding the determination of the central government to implement complete reforms (Wang et al., 2023). local officials were annually confronted with a plethora of campaign-style political tasks from the central government, wherein GSA seemed not necessarily taking precedence but endowed with considerable execution costs. It was only after observing repeated inspections by the central government in the subsequent year (signaling a significant shift from purely campaign-style enforcement to a regular regime) , that real actions were taken by local authorities and biodiversity transition costs were then factored into the pricing of MCB. We provide a more detailed summary of the factual logic related to the lagged effects in the Appendix B6.

For the validity of our identification, we also restrict our sample to the time before

GSA and estimate a variant model of Equation (1):

$$Spread_{bict} = \beta NNR_c \times YearTrend_t + \delta_i + \lambda_t + X_{bict} + \varepsilon_{bict} \quad (3)$$

In this model, the coefficient β of the interaction term $NNR_c \times YearTrend_t$ captures the difference in time trends between the treatment and control groups. We report the results in Table A2. Estimated coefficients of the interaction term are tiny and statistically insignificant, which also confirms no pre-existing differential trends.

4.2 Baseline Estimates

We present our baseline estimates in Equation (1). Column (1) controls only fixed effects to rule out all time-invariant issuer features and time shocks (year-quarter level) that unanimously affect all bonds. For Columns (2)-(4), we successively add controls, including bond-, issuer- and city-level variables. Standard errors are clustered at the city level in the parentheses. The results across all specifications are significantly positive. Specifically, the estimates in Column (4) imply that NNR municipalities suffered a larger increase in MCB spreads by around 25.06 basis points following GSA compared with non-NNR municipalities. This effect corresponds to an 12.71% increase from the sample mean (197.19 basis points) and a 18.45% increase from the sample standard deviation (135.84 basis points). These findings are consistent with the notion that the costs brought about by GSA are priced in the MCB market.

Turning to the event study shown in Figure 4, the gap in MCB spreads between NNR municipalities and non-NNR municipalities persisted and exhibited an upward trend following the implementation of GSA. This dynamic pattern aligns with the features of the enforcement in GSA. First, the central inspection on NNRs was not only conducted in 2017, but also were repeated annually in subsequent years. Under such a regular supervisory arrangement, it was difficult for local officials to undertake temporary accommodative actions. Thus, NNR municipalities were forced to allocate sustained inputs towards biodiversity conservation. Second, the process of local governments implementing the required rectification under GSA was not immediate and intensive but rather gradual and progressive. For example, in the survey of Wang et al. (2023), in June 2019, a local county government announced its wetland recovery work that would be completed by June 2022. Appendix B6 presents a more specific case in which a local government adopted a phased investment plan in the reform. In a nutshell, the trend observed in the event study test is consistent with facts about how transition costs are incurred.

4.3 Robustness Tests

We demonstrate the robustness of our baseline estimates to a range of alternative treatment intensities, spread measures, and sample frequencies. First, we examine two alternative measures of treatment intensities. At baseline, we specify a binary treatment variable and draw natural comparisons between NNR and non-NNR municipalities. We then move forward to more flexible measures of treatment intensities: the number of NNRs and the proportion of NNRs in the area of urban administrative areas. Both measures capture continuous variations in pressure on municipalities to manage NNRs. Table A3 and Panel A-B of Figure A2 report the results of replacing the binary variable with alternative measures. Incorporating more flexible variables into the estimation did not alter the significance of the coefficients.

Second, in Table A4 and Panel C-I of Figure A2, we report the results of alternative spread measures. Specifically, we successively utilize the quarterly median of spread, the quarterly mean of spreads, quarterly trading-volume-weighted spreads, and measures of replacing the benchmark with yields of the national bonds. All results accord with the baseline estimates.

Third, we examine the robustness using alternative data frequency of MCBs and the primary bond issuance market data. The corresponding sampling processes are the same for the quarterly secondary market datasets at baseline. Results are reported in Table A5 and Figure A3 in the order of monthly frequency, semi-annual frequency, annual frequency, and issuance sample. We see that the t-statistics are consistent and significant regardless of how we adjust the sample.

4.4 Contemporaneous Events

The current evidence suggests that GSA indeed led to an increase in the MCB spreads in NNR municipalities. One may wonder whether other events related to environmental issues occurring during the same period could also impact the MCB market. To address this concern, we examine the two important events that occurred around GSA: (1) “Central Inspection on Environmental Protection” and (2) “Nationwide Campaign to Prevent and Control Pollution” initiated by the Chinese central government.

Central Inspection on Environmental Protection (CIEP): In 2016, the Chinese central government launched a vital initiative to inspect and improve environmental conditions in each province.[29] This groundbreaking endeavor, approved by Beijing in July 2015, is commonly known as the Central Inspection on Environmental Protection. An essential aspect of this initiative was the establishment of a new mechanism for

[29] The Ministry of Ecology and Environment of the CPC has released detailed information on the Central Inspection on Environmental Protection (see: https://www.mee.gov.cn/ywgz/zysthjbhdc/)

environmental inspection: specific central inspection groups were dispatched to check local environmental protection and policy implementation on a provincial basis. Two rounds of these inspections have been conducted so far: the first round lasted from January 2016 to September 2017, while the second one took place from July 2019 to June 2022. Both rounds primarily focused on the environmental disruption across the region and related dereliction of duty in environmental work by local governments.

Nationwide Battle to Prevent and Control Pollution (NBPCP): In June, 2018, Beijing announced a comprehensive plan for pollution reduction, named Nationwide Battle to Prevent and Control Pollution[30]. The ambitious plan aimed to improve the country's environmental quality and mitigate relevant risks by drastically reducing the emissions of major pollutants. In addition to continuing to highlight the importance of GSA, three border parts of this plan were striking at that time, namely, the battles of protecting Blue Sky, Clear Water, and Clean Land, with explicit goals set on corresponding pollution reduction for 2020. For example, the proportion of excellent air quality days in cities should reach over 80%; sulfur dioxide emissions should be reduced by at least 15% compared with the level in 2015; the proportion of surface water bodies classified as Grade I-III should exceed 70%; the proportion of nearshore seawater classified as excellent (Grade I, II) should surpass 70%; The safe utilization rate of polluted plots should be over 90%.

The possible correlation between these two events and GSA lies in two aspects: Firstly, their implementations began around the same time. CIEP was launched in 2016, while NBPCP kicked off in 2018. GSA was initiated in the second half of 2017. Secondly, all of them target the regulation of environmental issues. CIEP and NBPCP mainly focus on overall environmental risk and pollution activities, whereas GSA concentrates on biodiversity issues, particularly those within NNRs. Thus, the former two events pose a potential threat to our identification.

To address this concern, we examine the impact of these events based on our baseline model. In Panel A of Table 3, we study CIEP by using four indicators: (1) *After the 1st round*, a dummy variable that equals one if it is after the first round of CIEP and zero otherwise; (2) *After the 2nd round* is a dummy variable that equals one if it is after the second round of CIEP and zero otherwise; (3) *In the 1st round*, a dummy variable that equals one if it is in the quarter of the first round of CIEP and zero otherwise; (4) *In the 2nd round*, a dummy variable that equals one if it is in the quarter of the second round of CIEP and zero otherwise. We find that after the first round of CIEP, MCB spreads rise slightly. However, CIEP cannot influence our conclusions on the impact of

[30] The corresponding policy document is the Guidelines on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Fighting the Battle to Prevent and Control Pollution, June 2018, (see: https://www.gov.cn/zhengce/2018-06/24/content_5300953.htm?eqid=804df71900054d45000000056461879e)

GSA since its coefficient remains significant.

Moving to NBPCP, Panel B of Table 3 presents its effects on the MCBs. Considering that NBPCP has quantifiable targets for pollution reduction and primarily focuses on enterprise pollution behaviors, we select four city-year-level pollution metrics in 2017: Air Quality Index, industrial sulfur dioxide emissions, industrial wastewater emissions, and industrial dust emissions. Air Quality Index, as disclosed by the Ministry of Ecology and Environment of the PRC, is a composite index weighted by concentrations of six major air pollutants, with higher scores indicating more severe local air pollution. The other three metrics, collected from the local Bureaus of Statistics, are scaled by the GDP of the secondary sector. We assume that the higher the pollution level, the greater the price that a city needs to pay to comply with NBPCP. We interact these metrics with *PostNBPCP*, a dummy variable that equals one if the first quarter of 2018 and zero otherwise, and then add interaction terms into our baseline specification. Results in Columns (1)-(5) show that the impact of GSA is not driven by NBPCP or pressure on pollution reduction.

4.5 Placebo Test

Another concern is that our results might reflect the effects of other features of nature reserves rather than transition costs incurred due to the GSA inspection. For example, the presence of nature reserves might constrain local economic development through approaches such as occupying urban land use (e.g., having complex topography and restricting human economic activities). This might have profound implications for the region's fiscal revenue streams for servicing public debts, increasing the risk profile and financing costs associated with MCBs. Meanwhile, there might be changes in attention to the biodiversity following GSA, which might also affect the pricing of MCBs in a way different from transition costs[31]. While having controlled fixed effects and a large set of covariates, we attempt to implement an additional placebo design.

We utilize nature reserves at lower levels, including the provincial, municipal, and county levels. Similar to NNRs, lower-level reserves may also restrict business by hindering land use for urban exploitation and drawing social attention to biodiversity. Despite this, GSA did not prioritize the inspection of non-NNR reserves. Due to the lack of political incentives, as well as the much larger number of non-NNR reserves than NNRs, it is also less likely that local officials took proactive effects to rearrange lower-level reserves. Therefore, non-NNR reserves can be an ideal placebo group, which helps to separate potential omitted effects related to the presence of NNRs. If

[31] The attention channel will be further discussed in Section 7.

GSA matters in our identification, we expect a minimal and insignificant effect with non-NNR reserves.

Based on the comprehensive list of nature reserves, we introduce *Provincial NR*, *Municipal NR*, and *County NR*, where each equals one if the city intersects with the corresponding type of reserves and zero otherwise, and then interact them with *Post*. Table 4 presents the results. As expected, variations in non-NNR reserves do not exhibit similar effects once NNRs are considered. Overall, the findings support GSA's role over alternative explanations related to other attributes of the presence of nature reserves[32].

5. From Transition Cost to Public Cost of Capital

Having established that GSA increased the MCB spreads, we next explore the underlying mechanism of this effect. As explicated in Section 2.2, GSA compelled local administrations to reinforce safeguarding NNRs, resulting in considerable short-term economic costs. On the one hand, GSA compelled unauthorized industries originally established within the NNRs to relocate, including mining, power generation, and tourism, leading to a possible decline in economic outputs and public revenue sources. On the other hand, the relocation and compensation for unregistered residents, the removal of illegal constructions, and the remediation of ecology on illegally occupied land within the NNRs, necessitated significant public spending.[33] Local governments were major investors and cost-bearers in this reform. The opportunity cost incurred, namely biodiversity transition cost, therefore, is expected to be the dominant pricing factor of MCB in the market regarding GSA.

We now examine the role of biodiversity transition cost by studying variations in (ex-ante) transition pressure across regions, changes in public spending on biodiversity and overall public creditworthiness, as well as heterogeneity in bond term structure. We also discuss alternative explanations for GSA influencing the financing activities of local governments.

5.1 Economic Activities within Reserves and the Transition Pressure

For the implementation and assessment of GSA, the primary regulatory focus is the human activities driven by non-scientific purposes within the NNRs. The central

[32] In practice, GSA occasionally extended beyond NNRs in certain years, yet inspections for these non-NNR reserves were not consistently repeated in subsequent years, indicating much weaker enforcement efforts. Moreover, according to official statements from the central government, routine supervisions and achievements attained of GSA primarily focus on NNRs, suggesting that only these reserves have undergone significant biodiversity transition and serve as the actual treatment. The placebo results in this section further confirm this observation.

[33] These expenses may include mending fragmented watersheds destroyed by hydroelectric power stations or rehabilitating barren mines into forests, as described in Section 2.2.

government employs the intensity of human activity to demonstrate the performance of GSA.[34] More pre-existing economic activities within NNRs would be associated with more decreases in government revenue and increases in expenditures on conserving natural capital (e.g., changes shown in Figure A1) to comply with GSA. Consequently, cities with more human economic activities within NNRs before the introduction of GSA would be expected to face heightened pressures for transition, which could lead to an amplified surge in MCB spreads. Fortunately, our geographic datasets described in Section 3.1 allow for a detailed characterization of human activities within NNRs, thereby facilitating our tests on the hypothesis of pricing biodiversity transition cost.

Developed Land within NNRs: We first utilize the area of developed land within NNRs to capture economic activities within the NNRs. In remote sensing, the land cover types comprise forest, grassland, farmland, wetland, urban built-up land, water bodies, glaciers, and so on. Among these types, urban built-up land and farmland have the highest intensity of economic activities, and face the most serious artificial reconstruction, far from the status of the primitive ecosystem. Therefore, transition pressure in NNRs with more farmland and urban built-up land is expected to be much higher. We sum these two types of land cover as the developed land. The raster data is from the China Land Cover Dataset constructed by Yang and Huang (2021).

We classify cities into three categories: NNR municipalities in the top quartile of the distribution of developed land area within NNRs in 2016, NNR municipalities not in the top quartile of the distribution of developed land area within NNRs in 2016, and non-NNR municipalities. Figure 5 illustrates unconditional dynamics in MCB spreads over time for these categories of cities. In the early stage, the trends of MCB spreads across all three groups were almost parallel. However, following GSA, MCB spreads began to diverge. NNR municipalities with large area of developed land within NNRs experienced the greatest surge in MCB spreads, followed by NNR municipalities with small area of developed land within NNRs, while non-NNR municipalities underwent the smallest increase. This pattern preliminarily supports the logic that GSA imposed a more significant impact on cities with vigorous-intensity economic activities within NNRs.

We then conduct a formal test on whether cities with large area of developed land within NNRs experienced a more significant increase in MCB spreads following GSA. Table 5 reports the results. In Column (1), we compare NNR municipalities with large area of developed land within NNRs to all other cities, and find that the former group were indeed more significantly affected by GSA on average. In addition, Column (2) shows that, NNR municipalities with different levels of developed land area within

[34] For instance, see: https://www.mee.gov.cn/ywdt/xwfb/202304/t20230427_1028560.shtml.

NRRs, relative to their non-NNR counterparts, experienced greater increases in MCB spreads after GSA. Meanwhile, those with more pre-existing developed areas within NNRs underwent a larger magnitude of influence, and the Wald test reveals that the difference is statistically significant. These findings confirm that cities with more economic activities within NNRs were more likely to face more increases in public financing costs, reflecting the market's concern about the expected burden of local governments on biodiversity conservation.

Nighttime Luminosity within NNRs: We also utilize nighttime luminosity as an alternative measure for economic activities. Specifically, we employ the raster data constructed by Zhang *et al.* (2021) and calculate the total nighttime light intensity within the boundary of NNRs as of 2016. We again classify cities into three categories: NNR municipalities in the top quartile of the distribution of nighttime light intensity within NNRs in 2016, NNR municipalities not in the top quartile of the distribution of nighttime light intensity within NNRs in 2016, and non-NNR municipalities.[35] Figure A4 plots the dynamics of MCB spreads in three groups. Columns (3)-(4) of Table 5 report the results of formal regression tests. We find that estimates based on nighttime light intensity consistently confirm that cities with more ex-ante economic activities within NNRs face greater transition pressure from GSA. The higher transition costs borne by local governments are then priced by investors in the MCB market as a larger rise in MCB spreads.

5.2 Public Spending on Biodiversity

While cross-sectional heterogeneity in ex-ante transition pressure provides insights into the financial market's expectations, a key issue still lies in whether and how much local governments have made concrete efforts in biodiversity conservation. Although we have introduced examples of how local governments governed NNRs following GSA in the preceding background section, one might still want quantitative evidence on public inputs under GSA.

Insufficient disclosure exists concerning the allocation of fiscal resources across different affairs. Thus, it is challenging to disaggregate specific portions dedicated to biodiversity conservation from local fiscal budget data, especially regarding general items such as salaries of civil servants responsible for nature reserves, compensation for resettlement of indigenous communities and businesses, and other associated taxes.

[35] It is worth mentioning that there are potential measurement errors of nighttime luminosity to proxy economic activities. Light sources outside NNRs may have spillover effects, while several types of human activity are also rarely done on a large scale at night (e.g., crop planting). These issues are merely faced by the measurement of land cover. Thus, we suggest exercising caution in interpreting the result of light grouping. It is more suitable as a robustness test for studying the pre-existing economic activities within NNRs and transition pressures from GSA.

Despite the difficulty in completely identifying how much is paid by municipalities in implementing GSA, we can explore some implications from a core spending pattern - public procurement contract, which is the primary comprehensive and detailed fiscal spending subject disclosed publicly in China, widely used in prior studies (Beraja *et al.* 2023). These contracts provide insights into the direct public investments in protecting biodiversity, which co-move with the aforementioned indirect fiscal parts.

Identifying NNR Contracts: We identify and analyze public procurement contracts related to national nature reserves, which are made by the responsible city governments and referred to as "NNR contracts" in this paper. The data for these contracts are sourced from the China Government Procurement website, maintained by the Ministry of Finance of the PRC.

We define NNR contracts as follows: NNR contracts must contain the name of an NNR and the term "reserve" (translated as "baohuqu" in Chinese) within the contract text. This is achieved by referencing the NNR name list and utilizing textual analysis. For instance, a contract for "Remote Monitoring Facility Project of Heixiazi Island National Nature Reserve" would be considered an NNR contract as it includes both the NNR name "Heixiazi Island" and the term "reserve" in its content. After removing duplicates, we identify 2,682 NNR contracts from 2015 to 2021. Next, we manually obtained the amounts for each contract. 2,635 contract records included amounts, and the overall missing rate of the amount data is less than 2%.

Analyzing NNR Contracts: According to the methodology of textual analysis explained above, the purchasers in NNR contract are all from NNR municipalities, as each NNR contract is explicitly associated with a specific NNR. Non-NNR municipalities have no obligation to cover NNR expense, and they indeed have a government procurement amount of zero for all years. Therefore, we cannot conduct a standard DID estimation, but instead directly aggregate all contract amounts by year to observe the unconditional trend.

Figure 6 presents the dynamics of the amount of NNR contracts. It is evident that in the two years prior to the implementation of GSA (i.e., 2015 and 2016), the proportion of NNR contracts to public procurement contracts across the country remained consistently around 0.013%. However, following GSA, the proportion of NNR procurement gradually increased year by year, reaching around 0.03% in 2021, an increase of about 2.3 times compared to the pre-GSA period. This gradual increase trend is also consistent with the spread trend we observed in the dynamics pattern of Figure 4. Specifically, when GSA began in 2017, local officials might fail to promptly undertake actions in response to the first-round inspection due to time constraints or adopt a wait-and-see attitude. Correspondingly, the increase in NNR contracts in 2017

was insignificant, only rising from 0.013% to 0.0144%. As GSA gradually became a regular regime rather than a campaign-style regulatory measure after 2018, and as local governments gradually carried out reification work on NNRs, NNR contracts increased. Therefore, by analyzing government procurement contracts, we observe a significant real rise in specific parts of fiscal spending on biodiversity preservation, which is clearly driven by the implementation time of GSA and provides additional evidence supporting the mechanism of pricing biodiversity transition costs through which GSA affects local public financing costs.

5.3 Local Public Creditworthiness

To make our argument on mechanism more complete, we further examine whether transition costs driven by GSA exacerbated local public creditworthiness. In practice, Chinese local governments have seldom issued special financing instruments with clearly defined sources of repayment funds for nature reserves (e.g. revenue bond). Instead, general fiscal budgets account for the most investments in biodiversity. In our sample, there is also no MCB issued for biodiversity conservation. Thus, MCB investors may exclusively pay great attention to the overall credit condition of the city government behind the MCB.

Local Fiscal Conditions: We first empirically examine whether GSA worsened local fiscal conditions. We calculate local fiscal deficit as the ratio of the difference between fiscal expenditure and revenue, to fiscal revenue. Greater government deficits typically indicate a poorer capacity for public debt repayment. We construct a city-year-level panel and test the effects of GSA on local fiscal deficit using the standard DID estimation, controlling the lagging logarithm value of the city's GDP and population. The year and city fixed effects are also included. Panel A of Table 6 reports the results. The difference between NNR municipalities and non-NNR municipalities in terms of fiscal deficits significantly increased by over 33% after the implementation of GSA. This finding suggests that local fiscal conditions deteriorated following GSA, which might be a key indicator that drove investors' concern about the public debt prepayment.

Local Public Debt Burden: In addition to the fiscal consequence, we also utilize cross-sectional variations in the pressure for local public debt repayment to explore the market's expectations of the default probability for MCBs. Theoretically, given the enormous costs caused by GSA, cities with high (ex-ante) public debt burden are more likely to face financial distress and find it challenging to service their bonds. Conversely, cities with low public debt burdens may still possess sufficient funds to safeguard the bondholders' interests. Therefore, in terms of bond pricing, MCB spreads

of the former regions would increase more than those of the latter.

To test this conjecture, we construct two measures of the local public debt burden. As introduced in Section 3.2, in China, all entities requesting authorization to issue a corporate bond in a given year are required to disclose their balance sheets for the current year and (at least) the three previous years. Besides, during the MCBs' outstanding period, the issuer should also publicly reveal its financial reports on a regular basis. Following Huang *et al.* (2020), we conduct a conservative calculation of the debt of LGFVs with bond outstanding, and aggregate LGFVs' total debts and interest-bearing debts to the city-year level as proxies of local public debt burden, respectively. We then define the dummy variable, *High debt burden*, which equals one if a city's level of public debt burden is in the top quartile of the distribution for the year before the bond trade and zero otherwise.

Panel B of Table 6 reports the differential effects of GSA on levels of local debt burden. We introduce a triple differences (DDD) specification based on Equation (1), with the triple interaction term *NNR*×*Post*×*High debt burden*. In this specification, the triple interaction term estimates the difference in treatment effects between the cities with high- and low-level public debt burden*s*. As is standard in the DDD approach, we also include the dual interaction terms, *NNR*×*Post, NNR*×*High debt burden*, *Post*×*High debt burden*, and *High debt burden*. Columns (1) and (2) show that the coefficients of the triple interaction term are both significantly positive, suggesting that the effect of GSA on MCB spreads for cities with high-level debt burden is greater than that for cities with low-level debt burden. This result further corroborates the notion that there is a concern about the expected probability of MCB default from MCB investors following GSA.

Effects on the MCB Term Structure: The complete recovery of biodiversity within NNRs and the generation of its sustained social benefits necessitate a long time horizon. However, the transition costs associated with GSA have already emerged in the short run. Thus, if the additional increase in public financing costs in NNR municipalities was driven by investors' concerns over transition costs, the pricing effects should be more pronounced on short-term MCBs. We employ a residual maturity of 3 years (or 4 years) as the criterion to classify between long-term and short-term bonds. As described in Section 3.2, the maturity of credit bonds issued in the Chinese market is shorter than that in the U.S. market. In our sample, both the mean and median of residual maturity of MCB observations fall within the range of 3 and 4 years. Table 7 presents that both long-term and short-term MCBs experienced the increase effect of GSA, while the impact on short-term bonds is significantly more substantial than that on long-term ones. The former finding may be attributed to the overall short maturity of

MCBs (with a maximum maturity of less than 15 years), while the latter finding aligns with the logic of pricing transition costs incurred in GSA.

5.4 Alternative Explanations for Public Financing Activities

Financing Demands of Local Governments: Based on the findings presented in the previous sub-sections, GSA has led to an increase in local governments' inputs on biodiversity-related matters. Consequently, an alternative channel through which GSA potentially contributes to the widening of MCB spreads is by exerting greater upward pressure on the demand curve of NNR municipalities in the financial market, instead of damaging local fiscal sustainability. We examine the impact of GSA on the quantity of local public financing based on the specification in Panel A of Table 6. We replace the dependent variable with the indicator that represents the amount of local public financing. Table A6 reports the effects on (1) the probability of new MCB issuance, (2) the amount of new MCB issuance, (3) the growth rate of total local public debts, (4) the growth rate of local public interest-bearing debts successively, at the city-year level. The latter two metrics are measured in a way consistent with methodology in Section 6.3.2. We find that GSA insignificantly hindered local public borrowing. This result suggests that even though local governments' demand for funds was growing after GSA, there was a constrained willingness of MCB investors to provide proceeds due to worrying about the creditworthiness of NNR municipalities. The latter effect played a dominant role in determining the amount of financing and drove up the MCB risk premium.

Local Political Risk: As outlined in Section 2.2, GSA holds officials accountable for negligence, which might affect the political turnover (ex-post) and change the promotion incentive for officials (ex-ante). For instance, in the "Qilian Mountain Incident", the area under the jurisdiction of Zhangye City recorded the most violations. Following the inspection by the central government, Shengwu Mao, the former municipal secretary of the CPC in Zhangye, and Zeyuan Huang, the incumbent mayor of Zhangye, both received the severe warning within the party, which primarily means they would not be allowed to be promoted to higher positions for a minimum period of one and a half years. It is also worth noting that the punishment one level higher than a severe warning leads to dismissal.

From the view of some MCB investors, GSA adds evaluation requirements for local officials, which possibly creates additional political risk. Thus, the perceived rise in risk premium could be attributed to the market's concern about the stability of the local political environment. To explore this conjecture, we first study changes in the positions of the municipal secretary of the CPC and the mayor, two primary leaders in

Chinese city governments. Again, using the specification in Panel A of Table 6, we find that GSA had an insignificant impact on local political turnover (Columns (1) and (3) of Table A7). We also employ the DDD specification in Panel B of Table 6 to study whether the impact of GSA is different during the first two years of the leading official's term. Prior studies reveal that officials in the early stages of their terms (i.e., the first two years) tend to have weaker political incentives, compared with their more established counterparts (Buntaine *et al.* 2022). Intuitively, during the late stage of their term, officials have limited leeway to incur penalties such as severe warnings that influence their promotion prospects for several years. As presented in Table A7, we do not observe significant heterogeneity across different stages of officials' tenures (Columns (2) and (4)). Overall, these results suggest that the potential increase in local political risk could not dominate the pricing effect of GSA.

6. Biodiversity Improvement and Value Versus Values

6.1 Proxy for Biodiversity Improvement

The preceding discussion has focused on the negative financial impact of GSA. How about its biodiversity impact? Has GSA genuinely improved local biodiversity as intended by Beijing, or is it a futile campaign?

Because biological systems are more complicated than physical systems, there have not been reliable and widely accepted metrics to measure the performance of biodiversity finance (Karolyi and Tobin-de la Puente, 2023), such as temperature and carbon emission used in climate finance. Neither are there currently complete panel statistics on various species at the prefecture level in China. Therefore, we center our attention on examining the changes occurring in a particular animal group - birds. Our proxy for biodiversity is partially driven by data availability --- we can access two specific datasets that capture the dynamics of bird species in China. More importantly, birds are an important indicator group of biodiversity due to their wide range and sensitivity to the environment.

The primary dataset is from the China Bird Report Center (CBRC), the leading Internet bird data recording and sharing platform. The data structure of the CBRC resembles that of the eBird Reference Dataset, a citizen science dataset comprising reports from users with detailed descriptions of their birdwatching trips, as well as the species of birds observed. We construct panel data of birdwatching activities at the city-quarter level from 2016 to 2021, using reports uploaded on the CBRC. We exclude the city-quarter observation with no birdwatching report, and then empirically explore the effects of GSA on the number of bird species observed through employing the DID specification. As shown in Table A8, following GSA, more bird species are reported in

NNR municipalities compared to non-NNR municipalities. Although the records from voluntary observation activities cannot convincingly represent the actual status of local wildlife, it seems reasonable to assume that the more abundant the bird population, the more likely it is to be observed. Therefore, the results are consistent with the notion that local biodiversity really benefited from more endeavors made by the government on biological conservation due to the enforcement of GSA. Furthermore, Table A8 presents that the intensity of birdwatching activities had no significant change around GSA, evidenced by the number of reports and reporters, indicating that the increase in bird species observed is not driven by more attention from birdwatchers.

Another complementary dataset is the monitoring information of birds from the Chinese National Ecosystem Research Network (CNERN), an information-sharing platform constructed by the Ministry of Science and Technology of the PRC, integrating resources of multiple existing field observation and research stations. Specifically, the data on birds is summarized from eight forest ecological stations[36], which conduct a systematic survey of birds every five years in corresponding areas. Since these stations are all located in NNR municipalities, we cannot employ a DID estimation and only perform descriptive statistics at the time series level. Figure A5 shows that the number of bird species surveyed declined by about a quarter in the first fifteen years of this century, and recovered a few following GSA, demonstrating a clear U-shape dynamic. This pattern provides further insights into the real positive effect of GSA on biodiversity.

The contrast between the biological implication and public financial costs of GSA prompts we to explore the role that the market's valuation of biodiversity plays in determining the price of MCB.

6.2 Information Asymmetry

Our previous discussions focus on explanations from the pecuniary preference of the market (i.e., the concern about the transition costs). However, it is possible that some investors' decisions are motivated by non-pecuniary values (Starks 2023). Suppose that there are a considerable number of investors who really care about biodiversity value for the sake of their non-pecuniary preference in the MCB market. However, they know little about the actual situation of NNRs, probably due to high information acquisition costs (e.g., conducting field visits and measuring biodiversity). In that case, the announcement of GSA plays a role in delivering delayed information on the poor management of biodiversity within NNRs. The major reactions of these

[36] The list of these eight stations: Ailao Mountain Station, Beijing Forest Station, Banna Station, Changbai Mountain Station, Dinghu Mountain Station, Gongga Mountain Station, Heshan Station, Huitong Station, Maoxian Station, Qingyuan Station, Shennongjia Station

impact investors to GSA may not be appreciating governments' forthcoming efforts, but blaming local authorities for past negligence and worrying about incurred biodiversity loss. If this assumption holds, the existence of these impact investors further increases local public financing costs.

We notice that the role of information asymmetry is critical for this channel to work. If impact investors can keep up to date with the situation of NNRs, GSA offers little new information and could not trigger significant incentives to concern biodiversity loss and punish NNR municipalities. Therefore, we collect newspaper coverage of NNRs from WiseNews, a leading Chinese newspaper aggregator. We develop two grouping metrics for the degree of information ambiguity about an NNR. The first one is whether an NNR municipality is in the top quartile in terms of the cumulative number of news covering NNRs under its management in 2016. The second is whether NNRs under a city's management are covered by *People's Daily*, a leading newspaper in China, in 2016. As shown in Table 8, NNR municipalities with different levels of newspaper coverage of their own NNRs see similar increases in MCB spreads around GSA, compared to non-NNR municipalities. Wald tests present insignificant heterogeneity. In addition, the information effect of GSA ought to gradually weaken over time theoretically, which is inconsistent with the pattern presented in Figure 4. In a nutshell, the heightened premium observed around GSA is not driven by information updating of biodiversity impact investors.

6.3 Investors' Valuation of Biodiversity Improvements.

We now consider an alternative channel through which preferences for biological well-being may influence the MCB markets. Investors may significantly reward NNR municipalities that demonstrate effective ecological improvements. This mechanism is crucial for rethinking how sustainable finance works. Although the net effect of the GSA reveals a prevailing market apprehension about the costs incurred by ecological transition, favorable investment strategies associated with biodiversity improvements can substantially mitigate the increase in the public cost of capital, thereby benefiting social welfare.

We categorize the birdwatching reports data introduced in Section 6.1 into two phases: from January 2015 to June 2017, and from July 2017 to December 2021. For each NNR municipality, we aggregate the number of bird species reported, reporters and reports during each interval, subsequently calculating the corresponding changes in the post-GSA period compared to the pre-GSA period. We compare the top quartile of NNR municipalities, which exhibit a substantial increase in bird species observed and the intensity of birdwatching activities around GSA, with other NNR municipalities.

The results presented in Table A9 reveal that these NNR municipalities with greater improvements in local biodiversity did not experience a significantly lower rise in MCB spreads, regardless of controlling amounts of NNR contracts. The role of pricing conservation costs behind biodiversity enrichment seems to be pervasive across groups.

In addition, the cross-sectional tests on ex-ante information asymmetry associated with NNRs discussed in Section 6.2 also indicate an insignificant impact of incentives to reward efforts on protecting biodiversity. Specifically, if NNRs with larger biological value are more likely to be covered by newspapers, then NNR municipalities with more NNR news have access to more favorable financing. This assumption implies the same sign of heterogeneity across municipalities with different levels of NNR news coverage as that under the hypotheses of punishment for dereliction and concern for biodiversity loss. However, as we have discussed in Section 6.2, Table 8 suggests a tiny disparity associated with ex-ante attention on NNRs. Consistent conclusions are also implied by the insignificant effects among non-NNR nature reserves shown in Table 4, if there is awareness spillover for biodiversity. Moreover, the social benefits of biodiversity restoration ought to become more evident in the long run, while the positive effects of GSA on spreads of long-term MCBs presented in Table 7 further indicate that valuing biodiversity do not play a dominate role in the financial market.

These findings underscore the absence of impact investments that favors ecological enhancement in the MCB market. In early 2024, Nobel Laureate Michael Spence emphasizes the empowerment of consumers, urging them to discern and support companies that prioritize climate change as a fundamental aspect of their business strategy.[37] Our work suggests that in the context of biodiversity conservation --- a similar issue of significance to social and environmental well-being --- there may still remain a significant gap in alignment and action.

7. Aggregate Financing Costs and Policy Implications

Our final section assesses the aggregate financing costs resulting from GSA. It is worth noting that a complete public borrowing cost analysis is beyond the scope of our analysis. We are only able to make a simple back-of-the-envelope calculation of the additional financing costs for LGFVs with outstanding MCBs. Specifically, we compute the interest-bearing debts of LGFVs and, subsequently, the rises in interest payments caused by GSA. We examine how these additional financing costs changed from 2013 to 2021 and how much GSA contributed to this change.

Overall Additional Financing Cost: As depicted in Figure 7, the debt cost escalated

[37] This concept of societal and environmental well-being also applies to biodiversity conservation (see more in: https://etinsights.et-edge.com/ai-looms-india-thrives-nobel-laureate-michael-spence-on-navigating-a-fractured-world/)

following the implementation of GSA: the actual public financing costs (the solid red line) remained below 50 billion dollars until 2018, after which these costs began to rise and reached approximately 120 billion dollars in 2021. To conduct a counterfactual analysis, we assume that the channel of NNRs is shut down by setting NNR to zero in Equation (1). In this scenario, the counterfactual public financing cost (the dashed blue line) was similar to the actual financing cost before 2018. However, it started to diverge after 2018, reaching around 107 billion dollars in 2021. The green bar describes the disparity between actual and counterfactual financing costs. Since GSA began to advance, the gap between actual and counterfactual financing costs has been increasing gradually year by year.

In Table 9, we present the estimates of the global biodiversity financial gap based on Deutz *et al.* (2020) and calculate the corresponding financial gaps that China needs to bear under three scenarios. In scenarios A, B, and C, China needs to bear the biodiversity financial gaps based on its share of global species, land area, and GDP, respectively. Given the estimated global annual financial gap of 711 billion dollars since 2019 by Deutz *et al.* (2020), for instance, China needs to spend 45.5 billion dollars per year on protecting biodiversity under scenario A. Meanwhile, the extra financing costs brought by GSA accounted for 12.73%, 19.82%, and 28.70% of the total costs (45.5 billion dollars) in 2019, 2020, and 2021, respectively. This suggests that, in practice, the cost of protecting biodiversity should involve not only direct investment but also indirect costs, such as the loss in financial markets due to changes in asset price (i.e., the cost of capital). Given the significant magnitude of these indirect costs (probably around three out of ten of the direct investments in 2021), scholars and policymakers should not overlook them in designing global biodiversity conservation frameworks.

Disaggregate Cost Burden Versus Biodiversity Improvement: Beyond assessing the economic significance of additional financing costs during biodiversity transition, we preliminarily consider how government-led conservation can become more efficient given the presence of financial frictions identified in this study. Figure A6 illustrates a raw map of the biodiversity improvement status and fiscal burden relative to additional financing costs of each NNR municipality around GSA. The vertical axis represents the proportion of cumulative additional financing costs to cumulative fiscal revenue for each NNR municipality from 2018 to 2021. The horizontal axis represents the increase in bird species observed following GSA relative to the level prior to the implementation, which has been discussed in Section 6.1 and 6.3.

As indicated in this unconditional scatter plot, there is substantial variation in the financial sustainability (i.e., the cost) and ecological sustainability (i.e., the benefit)

during the transition among NNR municipalities. Meanwhile, the cost and benefit parts are not highly correlated (indicated by the red fitted line). Thus, the central government faces the problem of optimal biological targeting in practice. A blanket reform approach like GSA can lower policy implementation costs (e.g., the complexity of regulatory standard). However, given the heterogeneity across regions, a more targeted plan is necessary for broader biodiversity conservation actions beyond NNRs to further improve social efficiency. This becomes particularly crucial in the context where private capital has yet to engage in biodiversity transition (called for by Karolyi and Tobin-de la Puente, 2023), necessitating public capital to move first proactively.

To shed some light on the optimal targeting in biodiversity transition, we partition Figure A6 into four quadrants, based on the sample median values of indicators in two dimensions. Specifically, (1) The lower right quadrant represents NNR municipalities with high biodiversity benefits and low financial burdens during transition, encouraging a broader conservation approach; (2) The upper left quadrant represents those with low biodiversity benefits and high financial burdens, suggesting a lower priority in practice; (3) The lower left quadrant represents those with low biodiversity benefits and low financial burdens, requiring more attention on biological enhancement; (4) The upper right quadrant represents NNR municipalities with high biodiversity benefits but high financial burdens, necessitating more intricate allocations designs (e.g, central fundings) to mitigate financial risks. Considering measurement errors associated with the metrics of birds aggregated at the city level and the restricted sample only encompassing NNR municipalities, the analysis above mainly serves as an initial benchmark.

8. Conclusion

We study the relationship between the transition to biodiversity conservation and the cost it imposes on local governments in terms of public financing. In particular, we exploit the Green Shield Action (GSA) in China as an exogenous shock from such a transition to local financial and fiscal burdens to study the responses from the municipal corporate bond (MCB) markets. Using a variety of data, including unstructured texts and zoning images, we present plausibly causal evidence that cities with National Natural Reserves (NNRs) experienced greater increases in public borrowing costs after the implementation of GSA. The effects come from the transition pressure from pre-existing economic activities within NNRs and increased public spending on biodiversity following the policy. These constraints and costs worsen local fiscal conditions, amplifying investors' concern about the probability of local government default. Our findings cannot be explained by financing demand of local governments, heightened political risk, or information disclosure. We also find that

though GSA improved biodiversity, investors are not considering these values when making investment decisions, neither are they financially punishing cities with appalling environmental degradations. Finally, we provide a conservative estimate of how much additional public financing costs GSA has incurred and how to best allocate central funding or prioritize biodiversity transitions. Given China's abundance of natural capital, economic scale, and the representative biodiversity challenge, our findings provide valuable initial benchmarks for future research and practice.

Our work likely has several policy implications. First, estimating the financing gap for biodiversity conservation requires considerations beyond direct investments for biodiversity transition. It also needs to account for any additional costs in the financial market. Thus, our study is informative given the current global acceleration of biodiversity loss and the urgent need for collective efforts to save natural capital. Second, we provide insights into how investors' lack of internalization of the (long-run) environmental benefits of government policies may hinder sustainable development goals. Policymakers must consider the reactions of financial markets when formulating relevant sustainable development policies. More detailed disclosure, dedicated financing vehicles, and promotions for the social recognition of biodiversity value constitute key steps in reversing the trend of nature capital loss.

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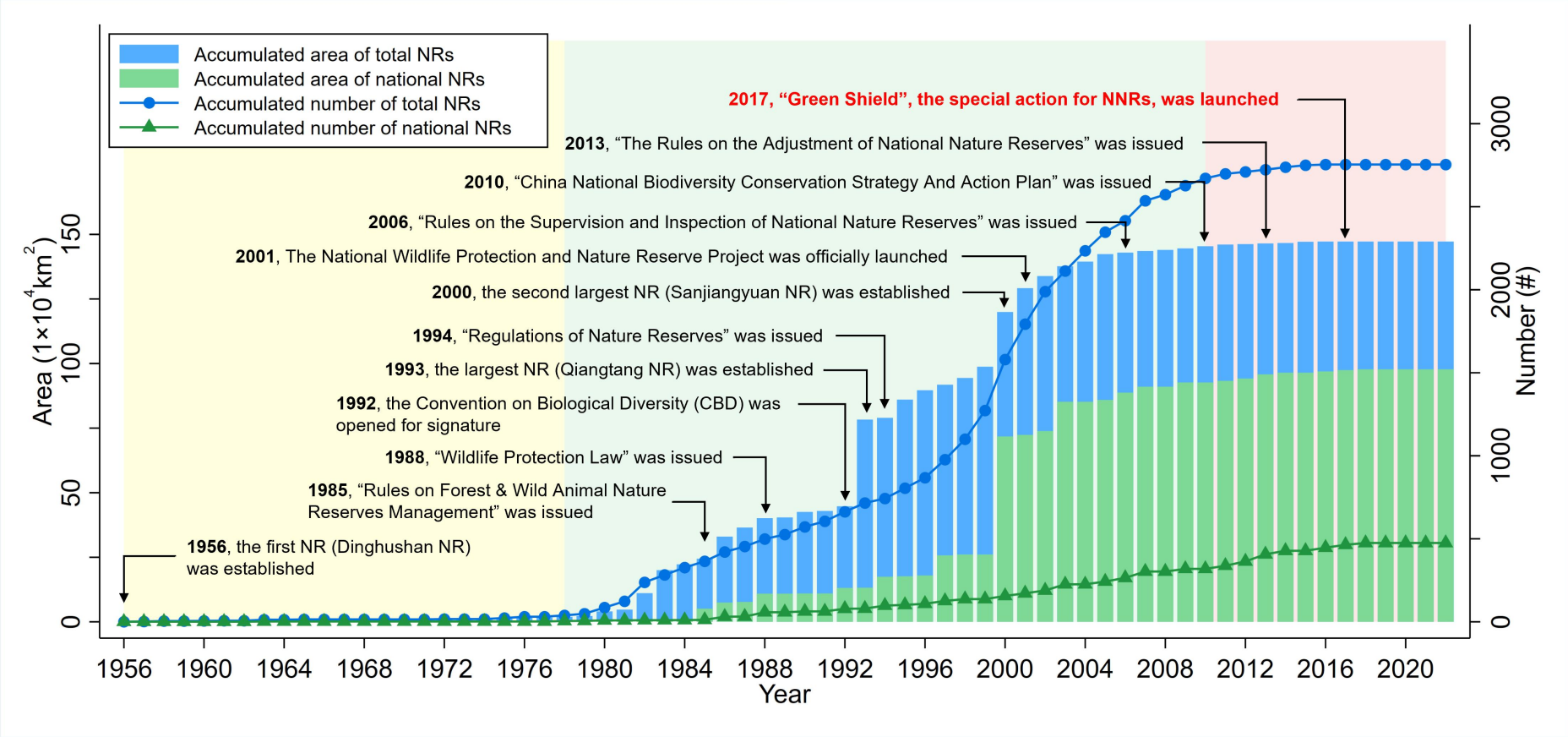
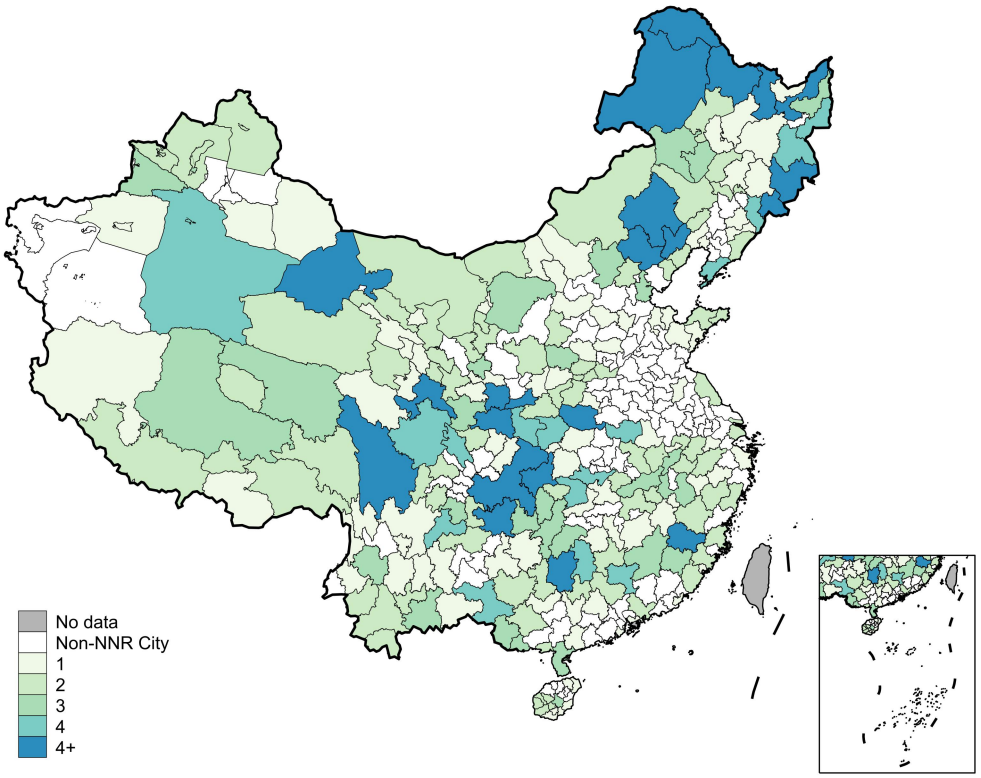
Figure 1

Development process of nature reserves and important relevant events in China



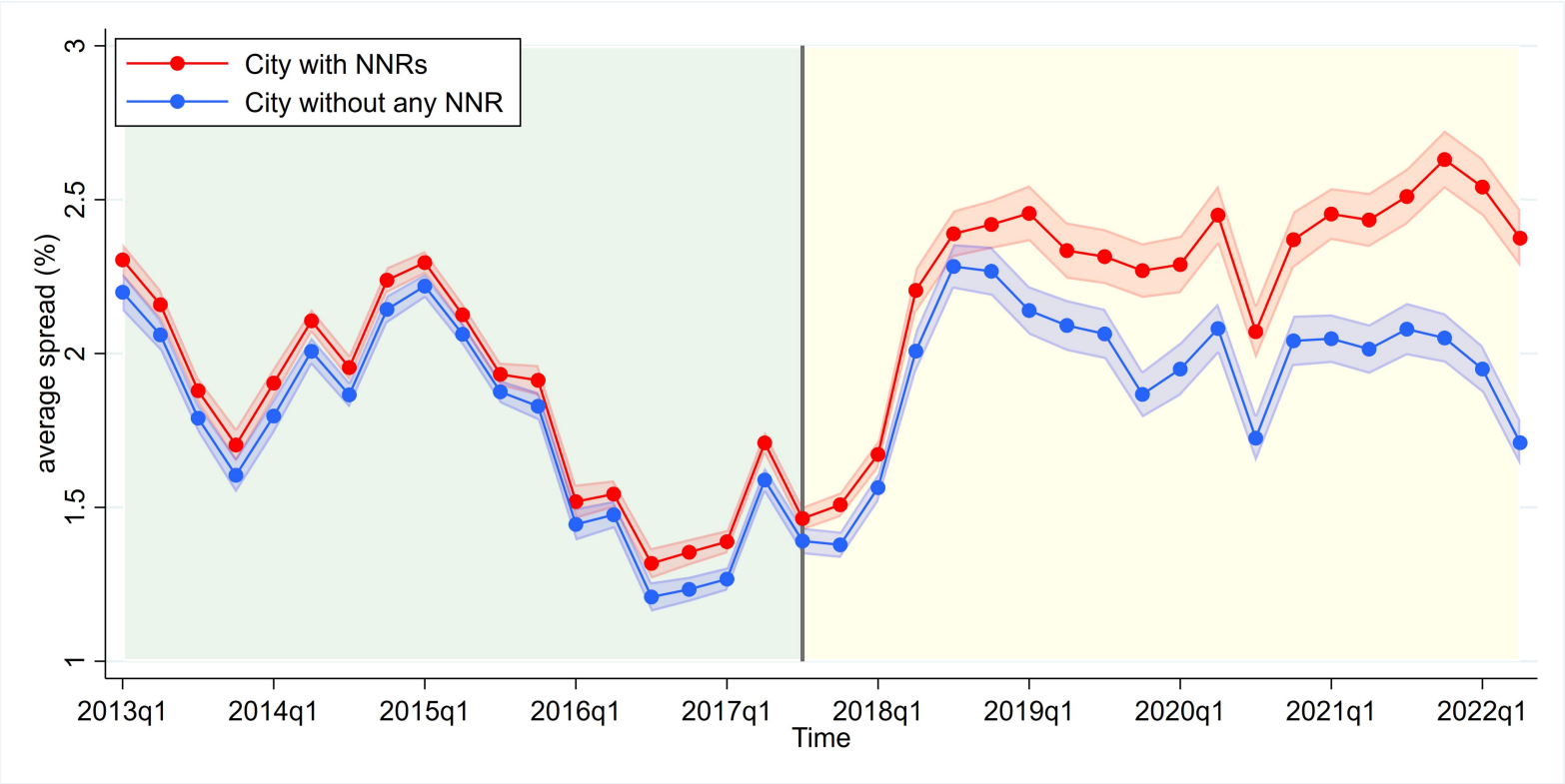
Notes: This figure illustrates the number (right axis) and area (left axis) of national nature reserves (NNRs) in China from 1956 to 2022. Important policies are also marked with arrows on the corresponding year.

Figure 2
The geographical distribution of NNRs at the city level



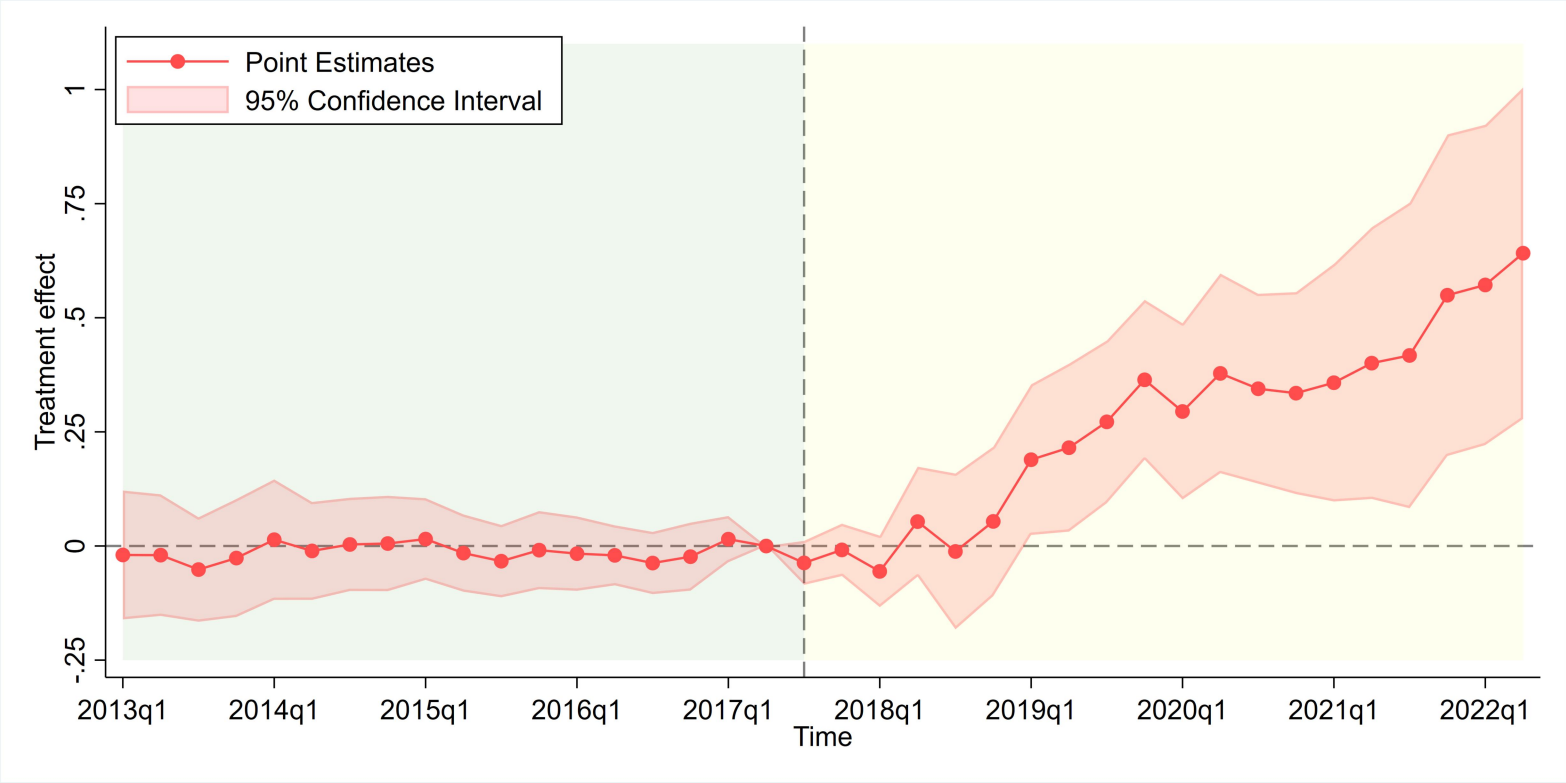
Notes: This figure illustrates the number of national nature reserves (NNRs) in each city in China as of 2016. The regional boundaries are delineated down to the city level. The legend depicts the range of the number of NNRs corresponding to each color depth.

Figure 3
The dynamics of MCB spreads over time



Notes: This figure depicts the average MCB spreads and 95% confidence interval for NNR municipalities and non-NNR municipalities. MCB spread is calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. The solid vertical line represents the time when the Green Shield Action (GSA) was launched.

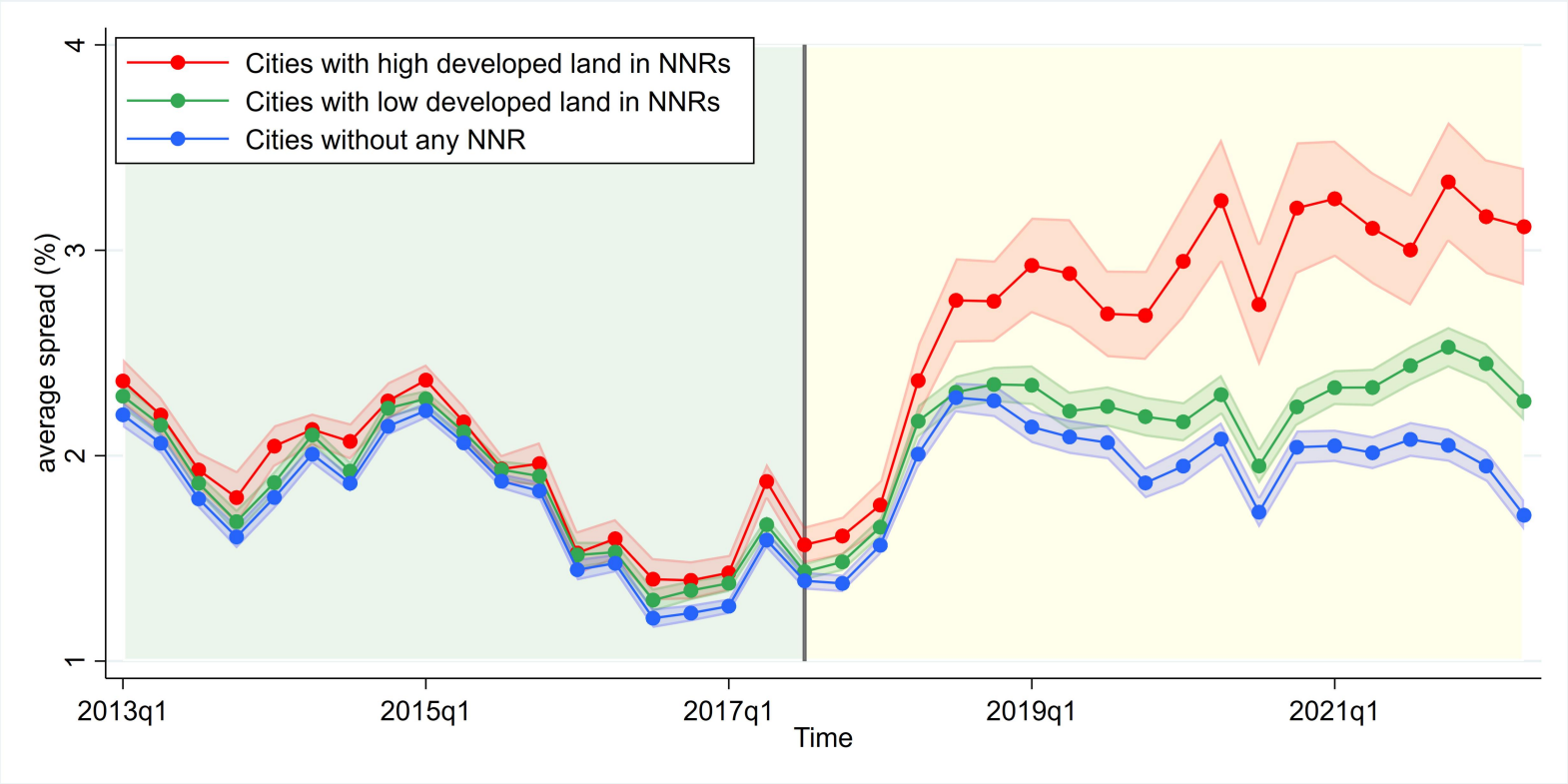
Figure 4
Changes in MCB spreads before and after GSA



Notes: This figure depicts the estimated differences in MCB spreads between NNR municipalities and non-NNR municipalities before and after GSA. The markers and capped spikes represent the OLS estimators and 95% confidence intervals. The dependent variable is the MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. The dashed vertical line represents the time when GSA was launched. The reference is the second quarter of 2017. The regression follows Equation (2). The standard errors are clustered at the city level.

Figure 5

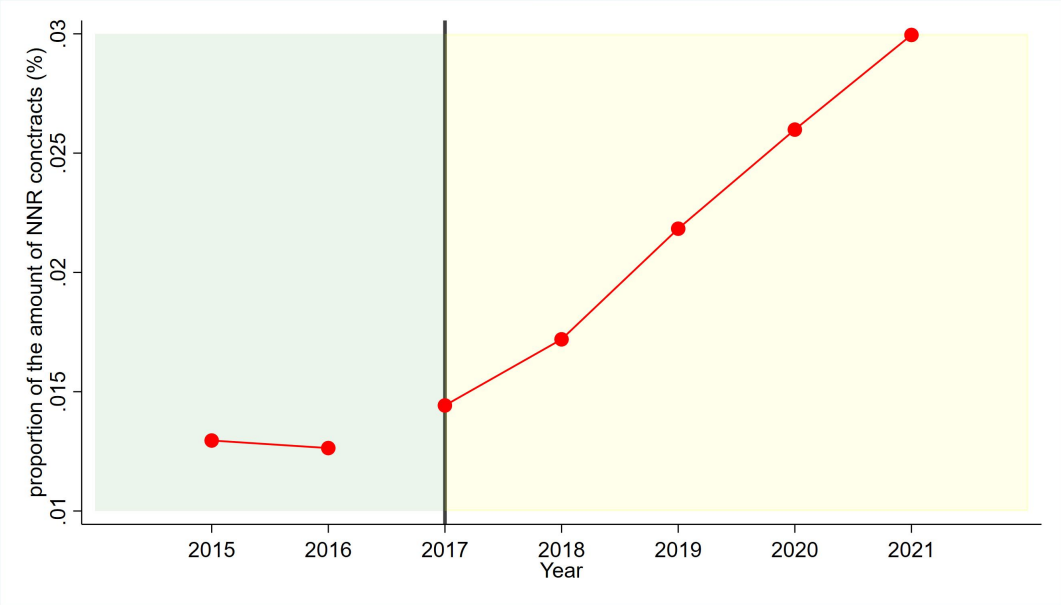
The dynamics of MCB spreads over time: developed land area in NNRs



Notes: This figure depicts the average MCB spreads and 95% confidence interval for cities in three groups: NNR municipalities in the top quartile of the distribution of developed land area within NNRs in 2016, NNR municipalities not in the top quartile of the distribution of developed land area within NNRs in 2016, and non-NNR municipalities. MCB spread is calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. The solid vertical line represents the time when GSA was launched.

Figure 6

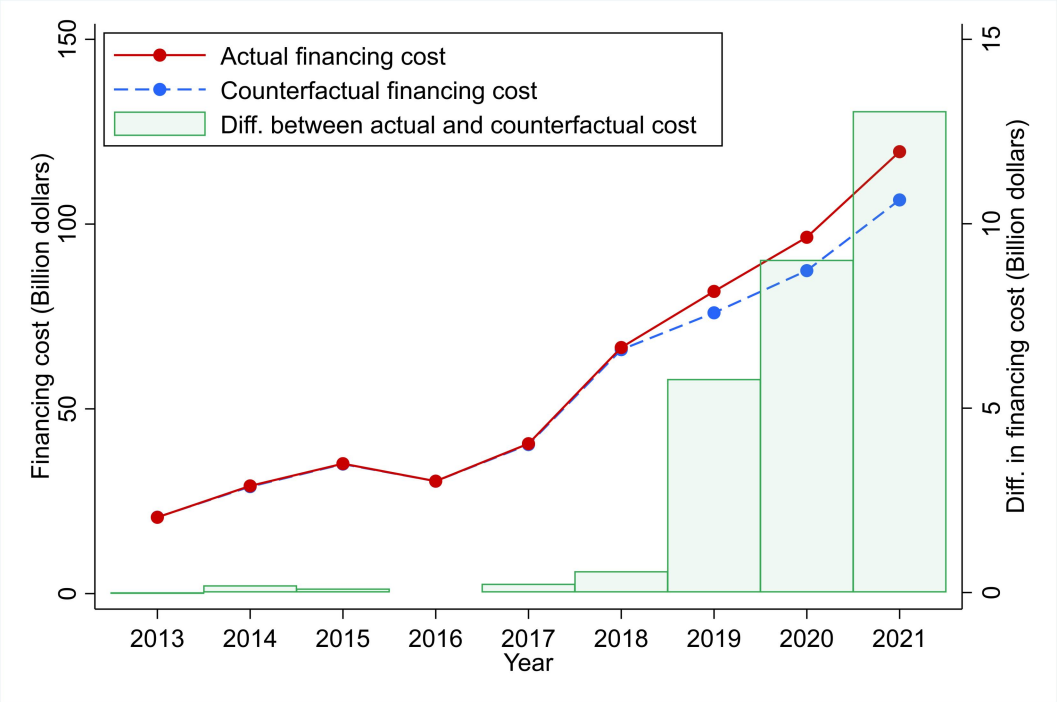
The dynamics of public procurement on national nature reserves over time



Notes: This figure illustrates the trend of the proportion of amounts of public procurement on national nature reserve to total public procurement from 2015 to 2021. The blue dots represent the proportion, the solid blue line represents the trend, and the red dashed line represents the year of GSA initiation.

Figure 7

Local public debt cost: comparison of true value and counterfactual estimates.



Notes: This figure plots the aggregate costs of LGFVs' debt service over time with and without GSA. The solid red line represents the actual aggregate costs of LGFVs' debt service (the left axis). The blue dashed line represents the counterfactual aggregate costs of LGFVs' debt service (the left axis). The green bar represents the difference between actual and counterfactual costs (the right axis) over time, that is, the additional cost of LGFVs' debt service brought about by GSA. The exchange rate between the US dollar and the Chinese RMB yuan is set as 1: 7.

Table 1
Summary statistics

Variable	Obs	Mean	Median	Std. Dev.	P25	P75
Spread	87,790	1.9719	1.6644	1.3584	1.0140	2.5086
NNR	87,790	0.5113	1.0000	0.4999	0.0000	1.0000
Post	87,790	0.6261	1.0000	0.4839	0.0000	1.0000
ln(Bond size)	87,790	2.2249	2.3026	0.5304	1.9459	2.5649
Time to maturity	87,790	3.8345	3.6822	1.7569	2.3644	5.1479
Option	87,790	0.6919	1.0000	0.4617	0.0000	1.0000
Secured	87,790	0.2306	0.0000	0.4212	0.0000	0.0000
Exchange	87,790	0.3231	0.0000	0.4677	0.0000	1.0000
Bond_rating	87,790	2.2901	2.0000	0.8225	2.0000	3.0000
Issuer rating	87,790	2.6534	3.0000	0.7323	2.0000	3.0000
ln(LGFV asset)	87,790	5.6437	5.5578	0.8766	5.0121	6.1868
LGFV leverage	87,790	52.0637	53.7886	13.2219	43.1942	62.3885
LGFV ROA	87,790	1.6971	1.4306	1.1559	0.9027	2.1695
ln(GDP)	87,790	6.0488	6.0736	1.0048	5.2858	6.8567
ln(Population)	87,790	1.7848	1.7785	0.7052	1.3618	2.2240

Notes: This table reports summary statistics in the baseline sample. The main dependent variable is MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. The control variables include three levels: bond level, issuer level, the city level, while the latter two are lagged by one year. Except for controls at the bond level, continuous variables are winsorized at the 0.5th and 99.5th percentiles.

Table 2
GSA and MCB spreads: Baseline estimates

	(1)	(2)	(3)	(4)
Variable	Spread	Spread	Spread	Spread
NNR×Post	0.2695***	0.2500***	0.2519***	0.2506***
	(0.1012)	(0.0939)	(0.0933)	(0.0872)
ln(Bond size)		-0.3677***	-0.3651***	-0.3598***
		(0.0423)	(0.0426)	(0.0418)
Time to maturity		-0.0654***	-0.0643***	-0.0586***
		(0.0091)	(0.0090)	(0.0085)
Option		0.8888***	0.8877***	0.8923***
		(0.0732)	(0.0734)	(0.0729)
Secured		-0.1862***	-0.1910***	-0.2188***
		(0.0609)	(0.0604)	(0.0587)
Exchange		0.2010***	0.2016***	0.2021***
		(0.0233)	(0.0233)	(0.0229)
Bond rating		0.3194***	0.3178***	0.3100***
		(0.0382)	(0.0382)	(0.0379)
Issuer rating		0.1204**	0.1095**	0.0910*
		(0.0562)	(0.0554)	(0.0546)
ln(LGFV asset)			-0.0854	-0.0262
			(0.0828)	(0.0776)
LGFV leverage			0.0026	0.0005
			(0.0021)	(0.0019)
LGFV ROA			-0.0127	-0.0031
			(0.0135)	(0.0130)
ln(GDP)				-0.5207**
				(0.2323)
ln(Population)				-2.0383***
				(0.5204)
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,790	87,790
Adjusted R^2	0.4931	0.5524	0.5526	0.5580

Notes: This table reports the regression results of the impact of GSA on MCB spreads. The dependent variable is calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and issuer fixed effects are included. Standard errors in parentheses are clustered at city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 3
GSA and MCB spreads: Major confounding events

Panel A: Central Inspection on Environmental Protection

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Spread	Spread	Spread	Spread	Spread	Spread
NNR×Post	0.2506***	0.2504***	0.2504***	0.2451***	0.2439***	0.2388***
	(0.0872)	(0.0870)	(0.0870)	(0.0871)	(0.0865)	(0.0866)
In the 1st round	0.0094		0.0094			
	(0.0151)		(0.0151)			
In the 2nd round		-0.0116	-0.0116			
		(0.0477)	(0.0477)			
After the 1st round				0.0957*		0.0932*
				(0.0492)		(0.0482)
After the 2nd round					0.0609	0.0583
					(0.0671)	(0.0666)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,790	87,790	87,790	87,790
Adjusted R^2	0.5580	0.5580	0.5580	0.5581	0.5580	0.5582

Panel B: Nationwide Battle to Prevent and Control Pollution

	(1)	(2)	(3)	(4)	(5)
Variable	Spread	Spread	Spread	Spread	Spread
NNR×Post	0.2276**	0.2359***	0.2232***	0.2288***	0.1986**

	(0.0945)	(0.0854)	(0.0849)	(0.0872)	(0.0901)
AQI×Post	-0.0023				-0.0022
	(0.0035)				(0.0037)
(Ind SO2/GDP2)×PostNBPCP		0.7710***			0.8076***
		(0.1270)			(0.1645)
(Ind dust/GDP2)×PostNBPCP			-0.2023		-0.4951***
			(0.1987)		(0.1816)
(Ind sewage/GDP2)×PostNBPCP				0.0007***	0.0002
				(0.0002)	(0.0003)
Controls	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes
Observations	85,714	84,719	84,619	83,473	83,473
Adjusted R^2	0.5534	0.5507	0.5467	0.5467	0.5500

Notes: This table reports the effects of contemporary major events on MCB spreads. Panel A focuses on the Central Inspection on Environmental Protection (CIEP). *In the 1st (2nd) round* is a dummy variable that equals one if the province is under the first-round (second-round) investigation of CIEP and zero otherwise. *After the 1st (2nd) round* is a dummy variable that equals one if the province has gone through the first (second) round of CIEP and zero otherwise. Panel B focuses on the Nationwide Battle to Prevent and Control Pollution (NBPCP). *AQI* is the Annual Air Quality Index at city level in 2017. *Ind SO2* represents annual industrial sulfur dioxide emissions at city level in 2017. *Ind sewage* represents annual industrial wastewater emissions at city level in 2017. *Ind dust* represents annual industrial dust emissions at city level in 2017. GDP2 represents gross domestic product of the secondary sector at city level in 2017. *PostNBPCP* is a dummy variable that equals one after the first quarter of 2018 and zero otherwise. The other designs are identical to Equation (1). The dependent variable is MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 4
GSA and MCB spreads: Placebo test

	(1)	(2)	(3)	(4)
Variable	Spread	Spread	Spread	Spread
NNR×Post	0.2533***	0.2519***	0.2332***	0.2324***
	(0.0868)	(0.0899)	(0.0870)	(0.0893)
Provincial NR×Post	-0.0779			-0.0933
	(0.1072)			(0.1119)
Municipal NR×Post		0.0087		-0.0161
		(0.0819)		(0.0845)
County NR×Post			0.1177	0.1289
			(0.0857)	(0.0917)
Controls	Yes	Yes	Yes	Yes
Year-quarter FE / Issuer FE	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,790	87,790
Adjusted R^2	0.5581	0.5580	0.5583	0.5584

Notes: This table reports the regression results of the impact of owning different types of nature reserves on MCB spreads around GSA. *Provincial NR* is a dummy variable that equals one if there is at least one provincial nature reserve in the city where the issuer is located, and zero otherwise. *Municipal NR* is a dummy variable that equals one if there is at least one municipal nature reserve in the city where the issuer is located, and zero otherwise. *County NR* is a dummy variable that equals one if there is at least one county nature reserve in the city where the issuer is located, and zero otherwise. The other designs are identical to Equation (1). The dependent variable is MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 5

GSA and MCB spreads: Pre-existing economic activities within NNRs

	Developed land area		Nighttime light intensity	
	(1)	(2)	(3)	(4)
Variable	Spread	Spread	Spread	Spread
High ex-ante economic activity in NNRs × Post (β_1)	0.3558***	0.4486***	0.2950***	0.3860***
	(0.0975)	(0.1058)	(0.0745)	(0.0835)
Low ex-ante economic activity in NNRs × Post (β_2)		0.2087**		0.2070**
		(0.0941)		(0.0987)
F statistics for testing $\beta_1=\beta_2$		4.7680**		3.6308*
Controls	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,790	87,790
Adjusted R^2	0.5574	0.5584	0.5574	0.5583

Notes: This table reports the heterogeneous effects of GSA on MCB spreads in pre-existing human economic activities within NNRs. *High ex-ante economic activity in NNRs* is a dummy variable that equals one if a city is in the top quartile of the intensity distribution of human economic activities within NNRs in 2016 among NNR municipalities. *Low ex-ante economic activity in NNRs* is a dummy variable that equals one if a city is not in the top quartile of the intensity distribution of human economic activities within NNRs in 2016 among the NNR municipalities. The intensity of human economic activities is measured by the developed land areas and nighttime light intensity within NNRs, respectively. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Other designs are identical to Equation (1). Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. F statistics is from the Wald test for the difference of regression coefficients. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 6
GSA and local public creditworthiness

Panel A: GSA and local fiscal condition		
	(1)	(2)
Variable	Spread	Spread
NNR×Post	34.9130***	33.1676***
	(10.8302)	(10.6703)
Controls	No	Yes
Year FE	Yes	Yes
City FE	Yes	Yes
Observations	2,754	2,754
Adjusted R^2	0.9420	0.9423
Panel B: GSA and MCB spreads: local debt pressure		
	(1)	(2)
Grouping indicator	Total debt	Interest-bearing debt
Variable	Spread	Spread
NNR×Post	0.1233	0.0914
	(0.0895)	(0.0946)
NNR×Post×High debt burden	0.3543**	0.3623**
	(0.1534)	(0.1480)
Other terms of triple difference	Yes	Yes
Controls	Yes	Yes
Year-quarter FE	Yes	Yes
Issuer FE	Yes	Yes
Observations	87,765	87,765
Adjusted R^2	0.5596	0.5595

Notes: This table reports the role of local creditworthiness in the relationship between GSA and MCB spreads. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city and zero otherwise. Panel A reports the effects of GSA on local fiscal conditions at the city-year level. *Fiscal deficit* is the ratio of the difference between annual fiscal expenditures and revenues, to fiscal revenues (in percentage). *Post* is a dummy variable that equals one in and after 2017 and zero otherwise. Year and city fixed effects, as well as the lagged logarithm of city's GDP and population are included. Panel B reports the heterogeneous effects of GSA on MCB spreads in local public debt burden. *High debt burden* is a dummy variable that equals one if a city's level of public debt burden is in the top quartile of the city distribution for the year before the bond trade and zero otherwise, where the debt burden is measured by city-year-level total debt and interest-bearing debt of LGFVs, divided by fiscal revenues, respectively. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and issuer fixed effects, as well as control variables defined in Equation (1), are included. Standard errors in parentheses are all clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 7

GSA and MCB spreads: Bond term structure

	Long term > 3 years			Long term > 4 years		
	Short term	Long term	Full sample	Short term	Long term	Full sample
	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Spread	Spread	Spread	Spread	Spread	Spread
NNR×Post	0.3614***	0.2146***	0.3332***	0.3142***	0.2091**	0.3013***
	(0.1152)	(0.0772)	(0.1112)	(0.0973)	(0.0892)	(0.0974)
NNR×Post×(Long Term=1)			-0.1624**			-0.1518**
			(0.0780)			(0.0722)
Other terms of triple difference			Yes			Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	35,201	52,589	87,790	48,336	39,454	87,790
Adjusted R^2	0.5882	0.6504	0.5589	0.5806	0.6657	0.5586

Notes: This table reports the heterogeneous effects of GSA on MCB spreads in bond term structure. The criterion to classify between long-term and short-term bond is whether is residual maturity is above 3 years in Columns (1)-(3) and 4 years in Columns (4)-(6), respectively. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Other designs are identical to Equation (1). Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. F statistics is from the Wald test for the difference of regression coefficients. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 8
GSA and MCB spreads: Information asymmetry

	Total news			People's Daily		
	Low Cover=0	High Cover=0	Full sample	Low Cover=0	High Cover=0	Full sample
	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Spread	Spread	Spread	Spread	Spread	Spread
High Cover×Post (β_1)	0.2229**		0.2453**	0.2567**		0.2648***
	(0.1082)		(0.1060)	(0.0999)		(0.1010)
Low Cover×Post (β_1)		0.2490**	0.2522**		0.2390**	0.2383**
		(0.0973)	(0.0976)		(0.1073)	(0.1065)
F statistics for $\beta_1=\beta_2$			0.0037			0.0526
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	53,420	77,277	87,790	61,421	68,944	87,790
Adjusted R^2	0.5651	0.5545	0.5580	0.5623	0.5536	0.5580

Notes: This table reports the heterogeneous effects of GSA on MCB spreads in information asymmetry. *High Cover* is a dummy variable that equals one if a city owns NNRs highly covered by newspaper in 2016 among NNR municipalities. *Low Cover* is a dummy variable that equals one if a city owns NNRs not highly covered by newspaper in 2016. For columns (1)-(3), the standard of highly covered is whether the city is in the top quartile of the intensity distribution of news cumulative news coverage of the NNRs in 2016 among NNR municipalities. For columns (4)-(6), the standard of highly covered is whether an NNR within the city is covered by the People's Daily in 2016. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Other designs are identical to Equation (1). Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. F statistics is from the Wald test for the difference of regression coefficients. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 9
Additional local public debt costs and corresponding economic significance

Scenario A: China bears the gap in biodiversity financing according to its share of global species (6.4%)						
Scenario B: China bears the gap in biodiversity financing according to its share of global land area (7%)						
Scenario C: China bears the gap in biodiversity financing according to its share of global GDP (18.5%)						
Year	2016	2017	2018	2019	2020	2021
Additional financing costs for MBC markets (Billion dollars)	0	0.24	0.58	5.79	9.02	13.06
Global biodiversity financing gap estimated by Deutz et al. (2020) (Billion dollars)				711	711	711
China's biodiversity financing gap in Scenario A (Billion dollars)				45.50	45.50	45.50
China's biodiversity financing gap in Scenario B (Billion dollars)				49.77	49.77	49.77
China's biodiversity financing gap in Scenario C (Billion dollars)				131.54	131.54	131.54
Proportion of financing costs in China's biodiversity financial gap in Scenario A (%)				12.73	19.82	28.70
Proportion of financing costs in China's biodiversity financial gap in Scenario B (%)				11.63	18.12	26.24
Proportion of financing costs in China's biodiversity financial gap in Scenario C (%)				4.40	6.86	9.93

Notes: This table presents results of a simple back-of-the-envelope calculation on the aggregate costs of GSA on the LGFVs' debt service and the corresponding economic significance. The exchange rate between the US dollar and the Chinese RMB yuan is set as 1: 7.

Appendix
A. Additional Tables and Figures

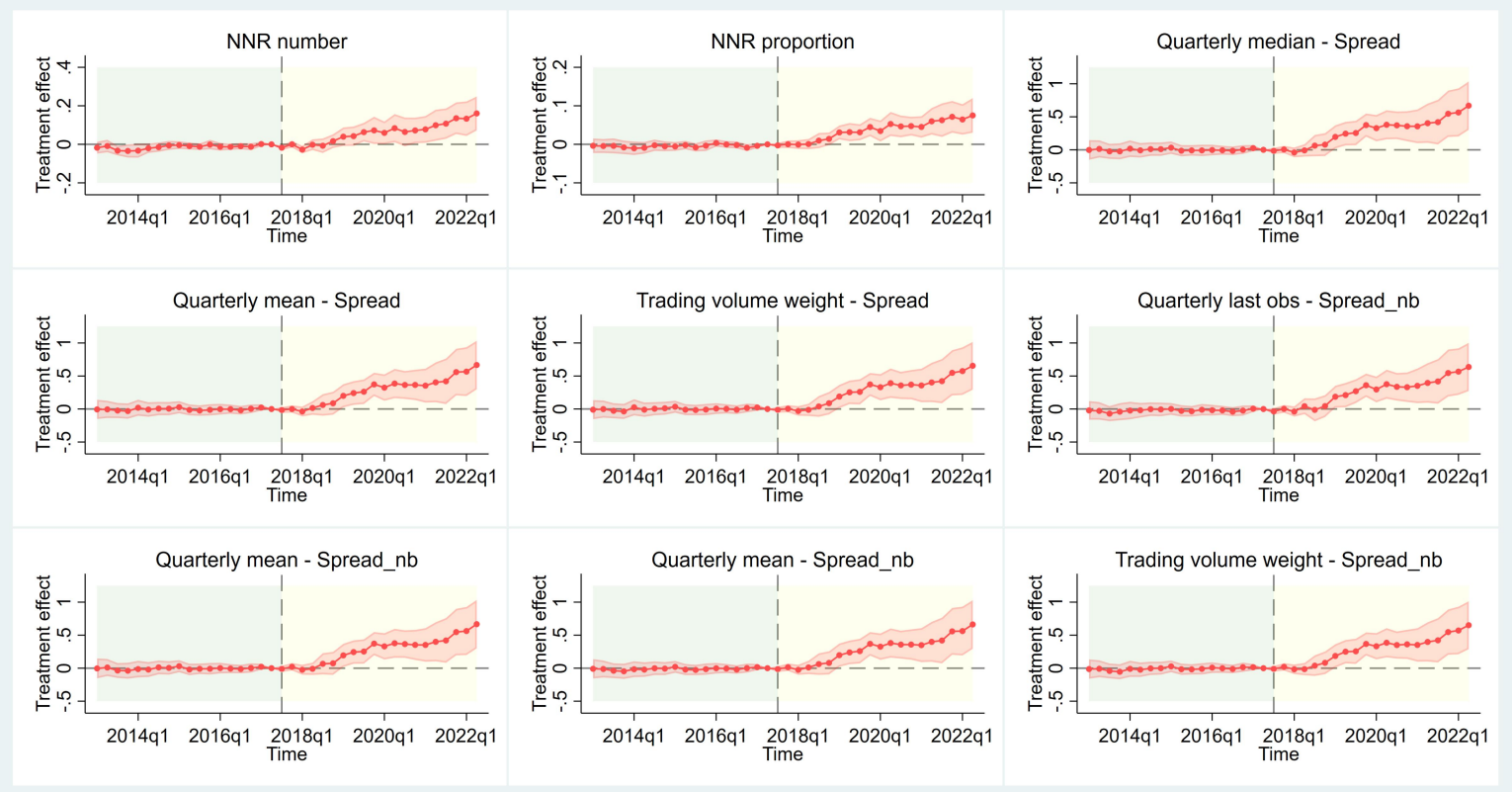
Figure A1
Changes in the biological condition of the Qilian Mountain NNR around GSA

Pre-GSA period Post-GSA period

Notes: This figure illustrates the contrast in the biological condition within the Qilian Mountain National Nature Reserve before and after GSA, from the perspectives of the disposal of illegal hydropower facilities (the upper part) and colliery (the bottom part). See more in: https://www.mee.gov.cn/ywgz/zysthjbhdc/dczg/202102/t20210206_820575.shtml.

Figure A2

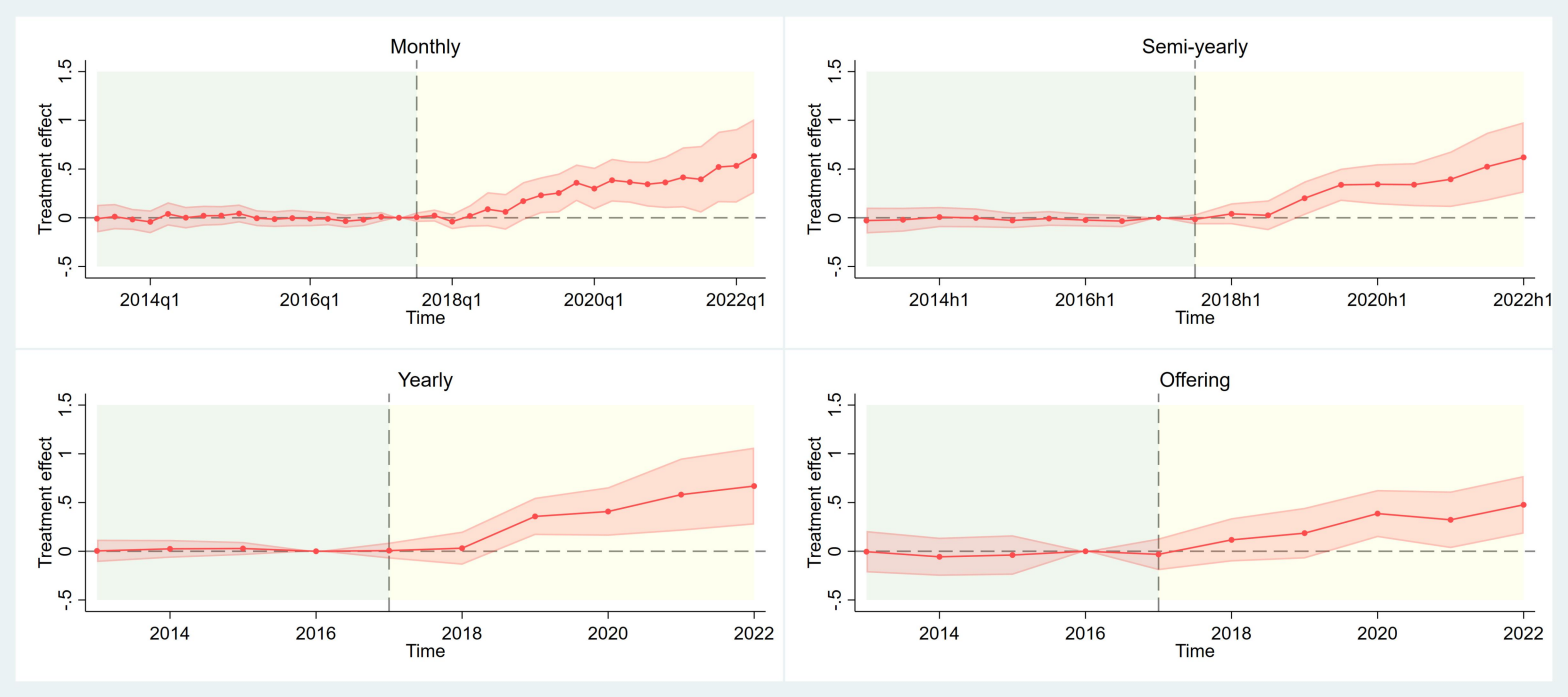
Changes in MCB spreads before and after GSA: Alternative measures of treatment intensity and spreads



Notes: This figure depicts results of robustness tests on estimated differences in MCB spreads between NNR municipalities and non-NNR municipalities, by replacing the main explanatory variable or the dependent variable of the specification in Figure 4. The alternative measures of treatment intensity used are the number of NNRs and the proportion of NNRs in the area of urban administrative areas within a city in Panel A-B, respectively. The alternative measures used are the quarterly median, the quarterly mean, and the quarterly trading-volume-weighted average of MCB spreads in Panel C-E, respectively, using the benchmark of CDB yield. Panel F-I replace the benchmark with the national bond yield.

Figure A3

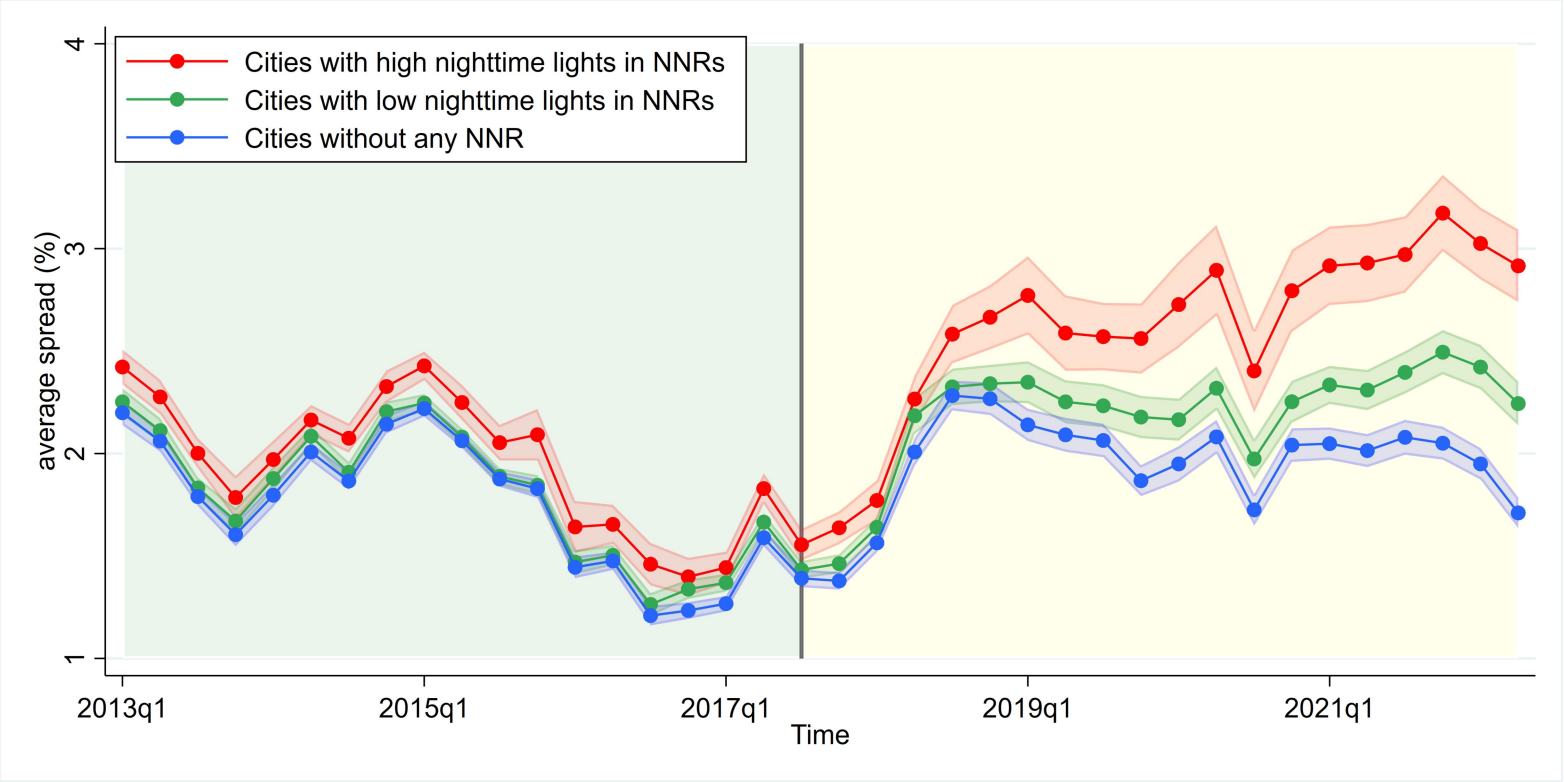
Changes in MCB spreads before and after GSA: Alternative frequencies of bond sample



Notes: This figure depicts the results of robustness tests on estimated differences in MCB spreads between NNR municipalities and non-NNR municipalities before and after GSA, by replacing the data frequency of the specification in Figure 4. The alternative frequencies of the bond sample are constructed by choosing the last observation of monthly frequency, semi-yearly frequency, and yearly frequency for each bond in Panel A-C, respectively. The estimation result with the bond offering sample is also shown in the Panel D.

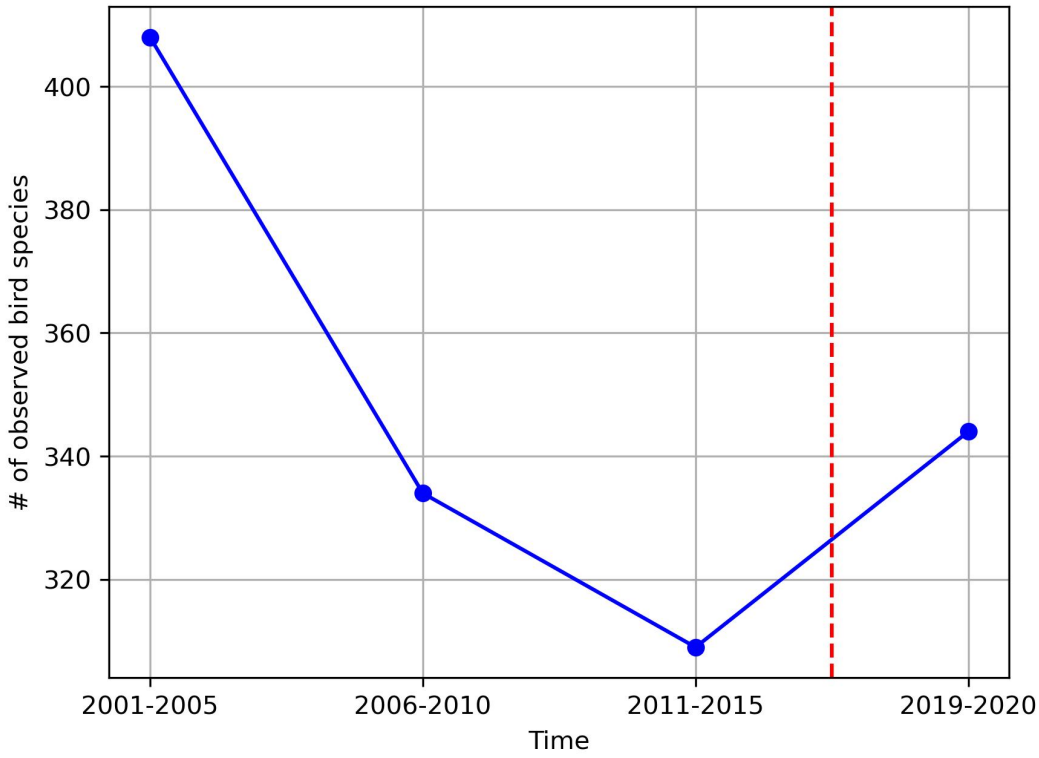
Figure A4

The dynamics of MCB spreads over time: Nighttime lights in NNRs



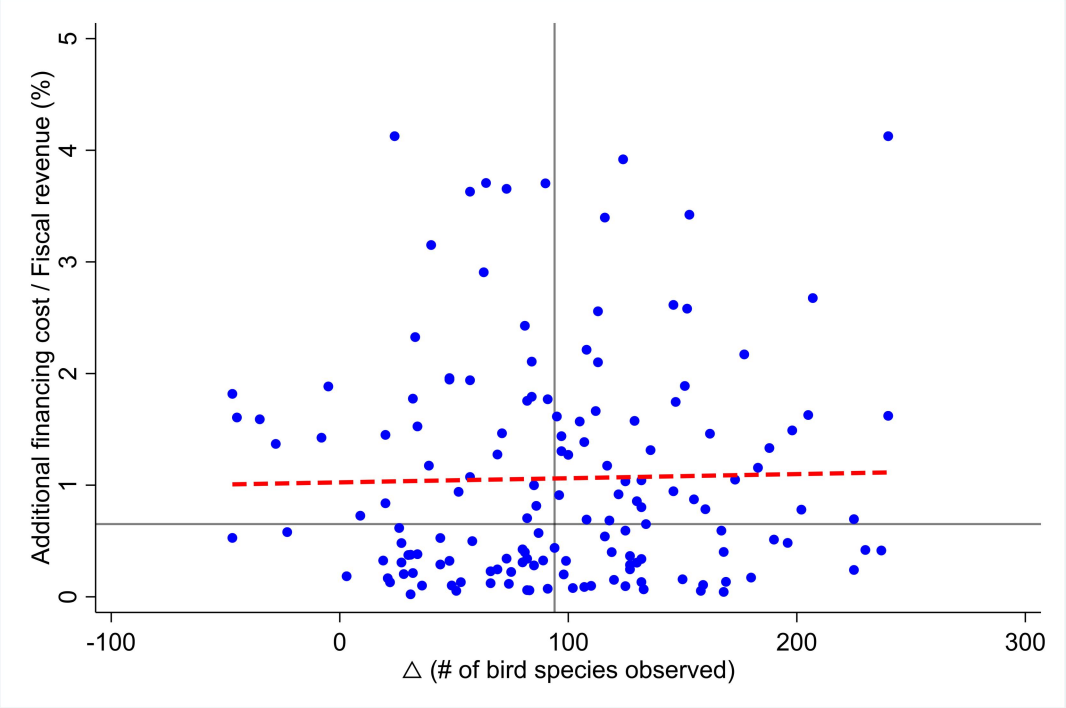
Notes: This figure depicts the average MCB spreads and 95% confidence interval for cities in three groups: NNR municipalities in the top quartile of the distribution of nighttime light intensity within NNRs in 2016, NNR municipalities not in the top quartile of the distribution of nighttime light intensity within NNRs in 2016, and non-NNR municipalities. MCB spread is calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. The solid vertical line represents the time when GSA was launched.

Figure A5
The dynamics of bird species observed over time



Notes: This figure depicts the total number of bird species surveyed every five years since the beginning of this century by the forest ecological stations connected with the Chinese National Ecosystem Research Network (CNERN). The dash vertical line represents the time when GSA was launched.

Figure A6
Additional financing costs and biodiversity improvement



Notes: This figure illustrates the distribution of NNR municipalities with available data according to additional financing costs and biodiversity improvement. Each blue dot represents a city. The vertical axis represents variations in the proportion of cumulative additional financing costs to cumulative fiscal revenue for each city from 2018 to 2021 (in percentage); The horizontal solid line represents the median level of the burden of additional financing costs. The level of biodiversity improvement is measured by the increase in bird species observed following GSA relative to their numbers prior to the implementation; The vertical solid line represents the median level of biodiversity improvement. The red dashed line is the fitted line representing the correlation between the burden of additional financing costs and biodiversity improvement across municipalities.

Table A1

Predetermined differences between NNR municipalities and non-NNR municipalities

Variable	NNR=1		NNR=0		Mean difference (1) - (0)	Difference p-value (1) - (0)
	Mean	Obs.	Mean	Obs.		
GDP (billion RMB)	188.9912	198	225.2031	114	-36.2119	0.2812
GDP per capita (RMB)	43.4656	198	46.6187	114	-3.1531	0.3295
GDP growth rate (%)	109.5848	198	109.7757	114	-0.1878	0.4370
Tertiary sector GDP proportion (%)	39.1984	198	39.5415	114	-0.3431	0.7532
Nighttime light intensity	9.0629	198	10.2039	114	-1.1410	0.1999
Housing price (thousand RMB / m^2)	4.8300	192	4.8948	113	-0.0647	0.8380
Fixed investment (billion RMB)	135.2605	198	153.4544	114	-18.1939	0.3076
Foreign direct investment (million dollar)	819.7843	189	828.2700	112	-8.4857	0.9713
Population (million)	3.9815	196	4.4008	114	-0.4193	0.3018
Employment (million)	1.0557	193	1.1497	113	-0.0941	0.6758
Local fiscal revenue (million RMB)	19.6958	198	19.3095	113	0.3863	0.9382
Local fiscal expenditure (million RMB)	34.4892	198	30.1783	113	4.3110	0.4451

Notes: This table represents the pre-GSA economic variable averages for NNR municipalities and non-NNR municipalities, the corresponding differences, and the p-value. The sample period covers 2013 to 2016. The exchange rate between the US dollar and the Chinese RMB yuan typically hovers around 1: 7.

Table A2
Trends in MCB spreads before GSA

Variable	(1) Spread	(2) Spread	(3) Spread	(4) Spread
NNR×Year linear trend	0.0070	0.0033	0.0036	0.0031
	(0.0131)	(0.0115)	(0.0113)	(0.0112)
Bond Controls	No	Yes	Yes	Yes
Issuer Controls	No	No	Yes	Yes
City Controls	No	No	No	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Observations	32,799	32,799	32,799	32,799
Adjusted R^2	0.4749	0.5473	0.5478	0.5485

Notes: This table reports the regression results of MCB spreads on time trends for the treatment and control groups. The dependent variable is MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Year* is a linear trend term for each year. Year-quarter and issuer fixed effects are included. Columns (1) includes no control variable, Columns (2)-(4) successively adds the bond-, the issuer-, and the city-level control variables. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A3
GSA and MCB spreads: Alternative measures of treatment intensity

Panel A: Number of NNR in corresponding city

	(1)	(2)	(3)	(4)
Variable	Spread	Spread	Spread	Spread
NNR number×Post	0.0536**	0.0575**	0.0577**	0.0599***
	(0.0256)	(0.0224)	(0.0225)	(0.0213)
Bond Controls	No	Yes	Yes	Yes
Issuer Controls	No	No	Yes	Yes
City Controls	No	No	No	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,790	87,790
Adjusted R^2	0.4922	0.5517	0.5519	0.5574

Panel B: Proportion of the NNR area in corresponding city area

	(1)	(2)	(3)	(4)
Variable	Spread	Spread	Spread	Spread
NNR proportion×Post	0.0378***	0.0345***	0.0345***	0.0339***
	(0.0081)	(0.0081)	(0.0081)	(0.0092)
Bond Controls	No	Yes	Yes	Yes
Issuer Controls	No	No	Yes	Yes
City Controls	No	No	No	Yes
Year-quarter FE	Yes	Yes	Yes	Yes

Issuer FE	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,790	87,790
Adjusted R^2	0.4931	0.5523	0.5524	0.5578

Notes: This table reports the regression results of the impact of GSA on MCB spreads using alternative measures of treatment intensity. The dependent variable is MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. Panel A employs *NNR number*, a count variable that represents the number of NNRs within the city where the issuer is located. Panel B employs *NNR proportion*, a continuous variable that represents the proportion of the area of NNR within the city where the issuer is located. Other designs are identical to Equation (1). *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and issuer fixed effects are included. Column (1) includes no control variable, Columns (2)-(4) successively adds the bond-, the issuer-, and the city-level control variables. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A4

GSA and MCB spreads: Alternative measures of spread

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Quarterly median	Quarterly mean	Trading volume weighted	Quarterly last obs	Quarterly median	Quarterly mean	Trading volume weighted
Variable	Spread	Spread	Spread	Spread_nb	Spread_nb	Spread_nb	Spread_nb
NNR×Post	0.2490***	0.2544***	0.2479***	0.2553***	0.2535***	0.2594***	0.2530***
	(0.0858)	(0.0863)	(0.0850)	(0.0871)	(0.0859)	(0.0862)	(0.0849)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	87,790	87,790	87,165	87,790	87,790	87,790	87,165
Adjusted R^2	0.5803	0.5831	0.5817	0.5555	0.5772	0.5802	0.5774

Notes: This table reports the regression results of the impact of GSA on MCB spreads using alternative measures of spread. The alternative measures used are successively the quarterly median of spread, the quarterly mean of spreads, the quarterly trading-volume-weighted weighted spreads in Columns (1)-(3), using the benchmark of CDB yield. Columns (4)-(7) replace the benchmark with the national bond yield. Other designs are identical to Equation (1). *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A5

GSA and MCB spreads: Alternative frequencies of bond sample

Variable	(1) Monthly Spread	(2) Semi-yearly Spread	(3) Yearly Spread	(4) Offering sample Spread
NNR×Post	0.2593***	0.2645***	0.2685***	0.2895***
	(0.0926)	(0.0874)	(0.0929)	(0.0957)
Controls	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Observations	166,092	52,703	31,984	8,953
Adjusted R^2	0.5807	0.5615	0.5819	0.8244

Notes: This table reports the regression results of the impact of GSA on MCB spreads using alternative frequencies of the bond sample. The alternative frequencies of sample are successively constructed by choosing the last observation of monthly frequency, semi-yearly frequency, and yearly frequency for each bond in Columns (1)-(3). The estimation results with the bond offering sample are also reported in Column (4). Other designs are identical to Equation (1). The dependent variable is MCB spread, calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city where the issuer is located and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Time (corresponding frequency, with quarter fixed effects for the offering sample) and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A6
GSA and the quantity of local public financing

Variable	(1) MCB issuance dummy	(2) MCB issuance amount	(3) Growth rate of LGFV debt	(4) Growth rate of LGFV interest-bearing debt
NNR×Post	-0.0272	-17.1747	-1.4019	-7.5896
	(0.0316)	(16.7900)	(3.9370)	(6.2892)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Observations	2,435	2,435	2,435	2,435
Adjusted R^2	0.3702	0.7601	0.1590	0.1422

Notes: This table reports the city-year-level regression results of the effects of GSA on the quantity of local public financing. *MCB issuance dummy* is a dummy variable that equals one if a city has a new MCB issuance in that year and zero otherwise. *MCB issuance amount* is a continuous variable that represents the the total amount of new MCB issued by a city in that year. *Growth rate of LGFV debt* is a continuous variable that represents the growth rate of city-year-level aggregated total debts of LGFVs with outstanding MCBs. *Growth rate of LGFV interest-bearing debt* is a continuous variable that represents the growth rate of city-year-level aggregated interest-bearing debts of LGFVs with outstanding MCBs. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city and zero otherwise. *Post* is a dummy variable that equals one for years in and after 2016 and zero otherwise. Year and city fixed effects, as well as the city-level control variables, are included. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A7

GSA and MCB spreads: Local political environment

	Municipal secretary of CPC		Mayor	
	(1)	(2)	(3)	(4)
Variable	Turnover	Spread	Turnover	Spread
NNR×Post	-0.0361	0.2382**	0.0087	0.2477***
	(0.0325)	(0.1042)	(0.0295)	(0.0945)
NNR×Post×(In the first 2 years of tenure)		0.0344		0.0180
		(0.0695)		(0.0613)
Other terms of triple difference		Yes		Yes
Controls	Yes	Yes	Yes	Yes
City / Year FE	Yes		Yes	
Issuer / Year-quarter FE		Yes		Yes
Observations	2,754	87,790	2,754	87,790
Adjusted R^2	0.0875	0.5584	0.1122	0.5582

Notes: This table reports the relationship between GSA and the local political environment. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city and zero otherwise. Columns (1)-(2) discuss the status of the municipal secretary of the CPC. Columns (3)-(4) discuss the status of the mayor. Columns (1) and (3) conduct tests on the city-year panel and examine the impact of GSA on the turnover of the corresponding official, with *Post* equaling one for years in and after 2016 and zero otherwise. Year and city fixed effects, as well as the city-level control variables, are included. Columns (2) and (4) conduct tests on the bond-quarter level and examine the differential impacts of GSA during specific stages of official's tenure, with *Post* equaling after the second quarter of 2017 and zero otherwise. *In the first 2 years of tenure* is a dummy variable that equals one if it is in the first two years of the corresponding official's term and zero otherwise. Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are all clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A8
GSA and birdwatching activities

Variable	(1) # of bird species observed	(2) # of reporters	(3) # of reports
NNR×Post	11.8240***	1.1893	3.7369
	(4.4624)	(0.9006)	(5.4310)
Controls	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Observations	4,704	4,704	4,704
Adjusted R^2	0.6125	0.3523	0.5829

Notes: This table reports the city-quarter-level regression results of the effects of GSA on the birding activities reported on the China Bird Report Center. The dependent variables in Columns (1)-(3) are successively the number of bird species observed, the number of birding reporters and the number of birding reports. *NNR* is a dummy variable that equals one if there is at least one national nature reserve in the city and zero otherwise. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Year-quarter and city fixed effects, as well as the city-level control variables, are included. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A9

GSA and MCB spreads: Biodiversity improvement

	△ (# of bird species observed)	△ (# of birdwatching reporters)	△ (# of birdwatching reports)
	(1)	(2)	(3)
Variable	Spread	Spread	Spread
High bio improvement×Post (β_1)	0.3127**	0.2901**	0.3000**
	(0.1319)	(0.1128)	(0.1226)
Low bio improvement×Post (β_1)	0.2420**	0.2433**	0.2422**
	(0.0984)	(0.1073)	(0.1008)
F statistics for $\beta_1=\beta_2$	0.2892	0.1518	0.2159
Controls	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Observations	80,694	80,694	80,694
Adjusted R^2	0.5577	0.5577	0.5577

Notes: This table reports the heterogeneous effects of GSA on MCB spreads in biodiversity improvement. *High bio improvement* is a dummy variable that equals one if a city is in the top quartile of the biodiversity improvement among NNR municipalities. *Low bio improvement* is a dummy variable that equals one if a city is not in the top quartile of the biodiversity improvement among NNR municipalities. The level of biodiversity improvement is measured by the increase in bird species observed, birdwatching reporters and birdwatching reports following GSA relative to their numbers prior to the implementation, respectively. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Other designs are identical to Equation (1). Year-quarter and issuer fixed effects, as well as the control variables, are included. Standard errors in parentheses are clustered at the city level. F statistics is from the Wald test for the difference of regression coefficients. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A10
Additional definitions of variables.

Variable	Definition
ln(Bond size)	The logarithm of a bond issuing amount, in hundred million yuan RMB.
Time to maturity	The residual maturity of a bond traded, in year.
Option	A dummy variable that equals one if a bond is option-embedded and zero otherwise.
Secured	A dummy variable that equals one if a bond is secured and zero otherwise.
Exchange	A dummy variable that equals one if a bond is traded on the exchange market and zero otherwise.
Bond rating	A numerical number converted from the real letter grades of a bond, by assigning 1 to AAA, 2 to AA+, 3 to AA, 4 to AA-, 5 to A+, 6 to A, 7 to A-, 8 to grades below A.
Issuer rating	A numerical number converted from the real letter grades of an issuer, by assigning 1 to AAA, 2 to AA+, 3 to AA, 4 to AA-, 5 to A+, 6 to A, 7 to A-, 8 to grades below A.
ln(LGFV asset)	The logarithm value of the total assets of corresponding LFGV at the end of the year before the bond trading day, in hundred million yuan RMB.
LGFV leverage	The ratio of total liabilities to total assets of corresponding LFGV at the end of the year before the bond trading day, in percentage.
LGFV ROA	The ratio of earnings before interest and tax (EBIT) and average total assets of the corresponding LFGV in the end of the year before the bond trading day, in percentage.
ln(GDP)	The logarithm of gross domestic product of corresponding city in the year before the bond trading day, in billion yuan RMB.
ln(Population)	The logarithm of population of corresponding city in the year before the bond trading day, in million people.
Spread_nb	The difference between the municipal corporate bond yield and national bond yield on the same day and of the same maturity, in percentage.

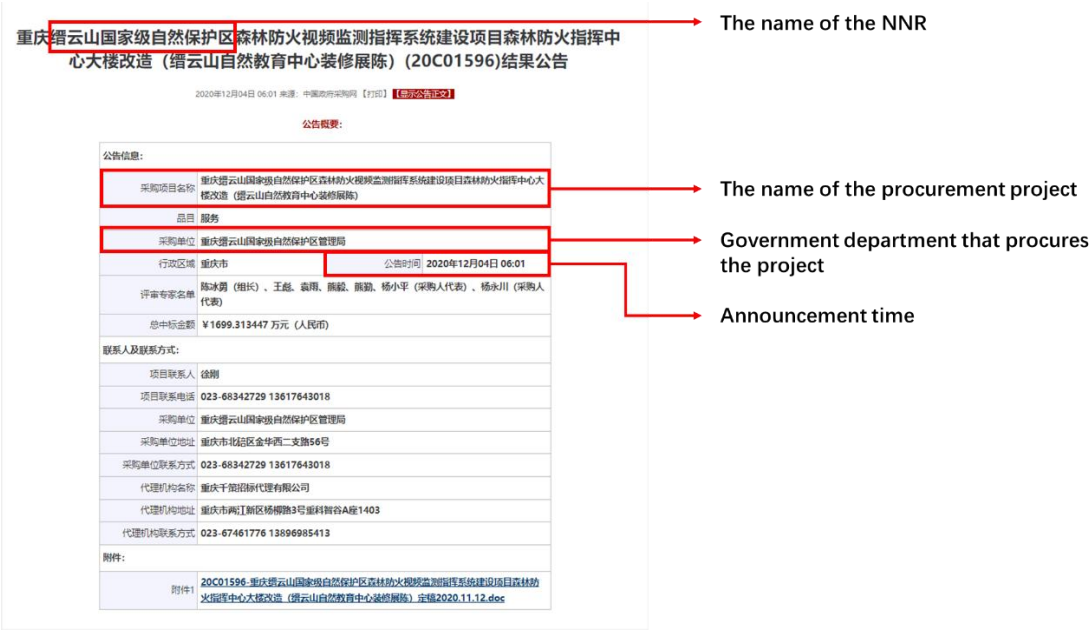
Notes: This table reports the definitions of variables that may be not explained in detail in notes of corresponding tables and figures.

B. Additional materials on institutional background

B1. Several examples of government procurement on NNRs

Figure B1

The announcement of "Chongqing Jinyun Mountain National Nature Reserve Forest Fire Video Monitoring and Command System Construction Project, Forest Fire Command Center Building Renovation (Jinyun Mountain Nature Education Center Renovation)"

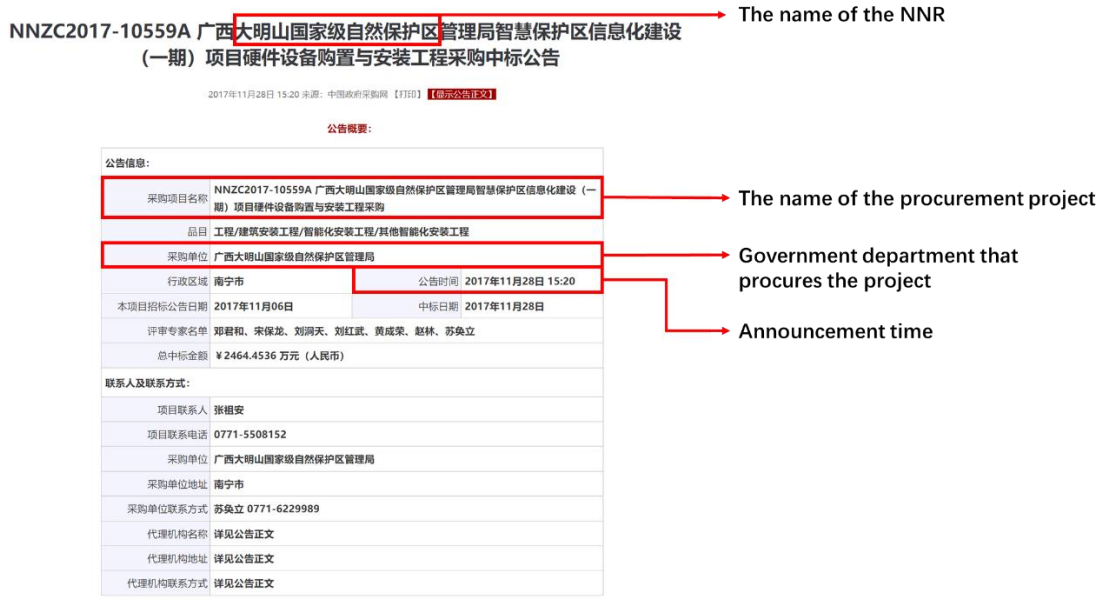


Note: This government procurement contract is about the construction project of the forest fire video monitoring and command system in the Jinyun Mountain National Nature Reserve in Chongqing, especially the renovation of the command center building, as well as the decoration and exhibition work of the Jinyun Mountain Nature Education Center. The purpose of this contract is to establish an effective forest fire video monitoring system to enhance the capacity for fire prevention and response, thereby protecting the forest within the nature reserve. Additionally, through the renovation of the Nature Education Center's exhibition, it aims to enhance public education and awareness of nature conservation and forest fire prevention. The announcement was made on December 4, 2020. The government department that procured the project is Chongqing Jinyun Mountain NNR Administration. [38]

[38] See more details in: https://www.ccgp.gov.cn/cggg/dfgg/zbgg/202012/t20201204_15555995.htm

Figure B2

The announcement of "Guangxi Daming Mountain National Nature Reserve Administration's Smart Nature Reserve Informatization Construction (Phase I) Project, Hardware Equipment Procurement and Installation Engineering"



Note: This government procurement contract is related to the installation of hardware equipment for the "Intelligent Protection Area Information Construction" project of the Guangxi Daming Mountain National Nature Reserve Administration. The objective of the contract is to install the necessary intelligent hardware equipment, which will contribute to improving the management level and efficiency of the nature reserve through information system construction, thereby enhancing the monitoring and protection capabilities of the ecological environment. The announcement was made on November 28, 2017. The government department that procured the project is Guangxi Daming Mountain NNR Administration. [39]

[39] See more details in: https://www.ccgp.gov.cn/cggg/dfgg/zbgg/201711/t20171128_9239731.htm

Figure B3

The announcement of "Construction of Vegetation Restoration Project in Dongchong Area of Xiadu District, Yangtze Alligator Nature Reserve, Anhui"

Note: This document is a public announcement regarding the vegetation restoration project in the Xiadu area of the Yangtze Alligator National Nature Reserve in Anhui. The procurement aims to restore the vegetation within the reserve, providing better living conditions for the Yangtze alligator and other wildlife and plants. The announcement was made on February 7, 2018. The government department that procured the project is Yangtze Alligator National Nature Reserve Administration. [40]

[40] See more details in: https://www.ccgp.gov.cn/cggg/dfgg/zbgg/201802/t20180207_9566659.htm

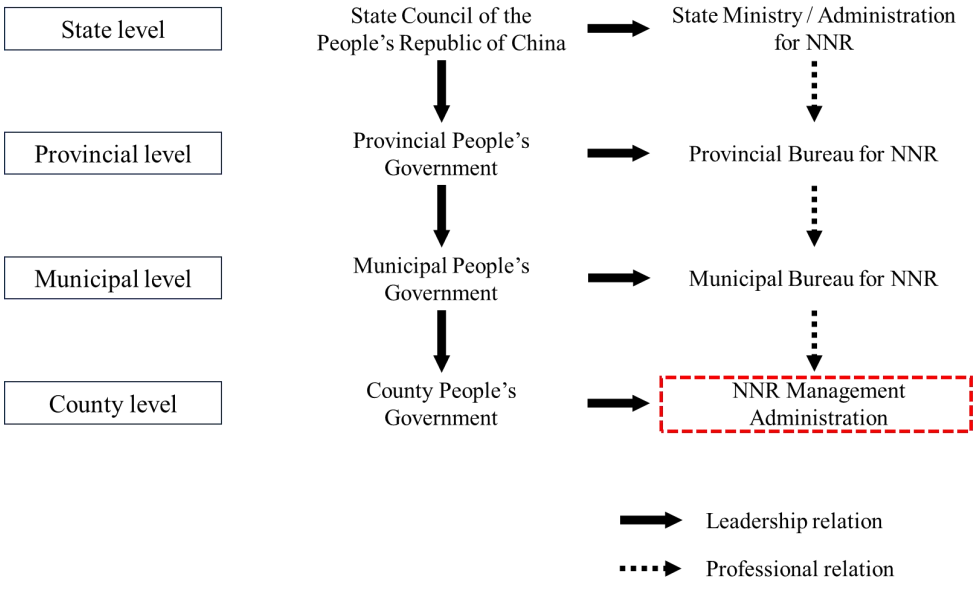
B2. Institutional arrangements for NNRs.

In China, local governments are primarily responsible for managing, supervising, and conserving NNRs within their jurisdictions. Each NNR is typically governed by a dedicated administration committee that handles its routine operations. The governing structure of these committees is termed “dual leadership”. Two types of leadership thereof are distinguished: one is called “leadership relation” in which territorial local government controls the personnel, financial budget and material resources of the functional agencies related to NNRs, and the other is called “professional relations” in which superior agencies supervise the daily affairs of agencies at lower levels in carrying out their defined functions.

For the administration committee of nature reserve, the local government has the decision-making power over important matters such as financial allocation and personnel appointment and removal, while the higher-level authority (e.g., the forestry bureau) only maintains a professional leadership relationship with the committees. In the context of decentralized governance, nature reserve management responds more to local government than to the higher-level authority (Wang et al., 2023). Generally, the institutional structure of nature reserve organization can be illustrated as the Figure B4 below.

Figure B4

The normal institutional structure of nature reserve organization

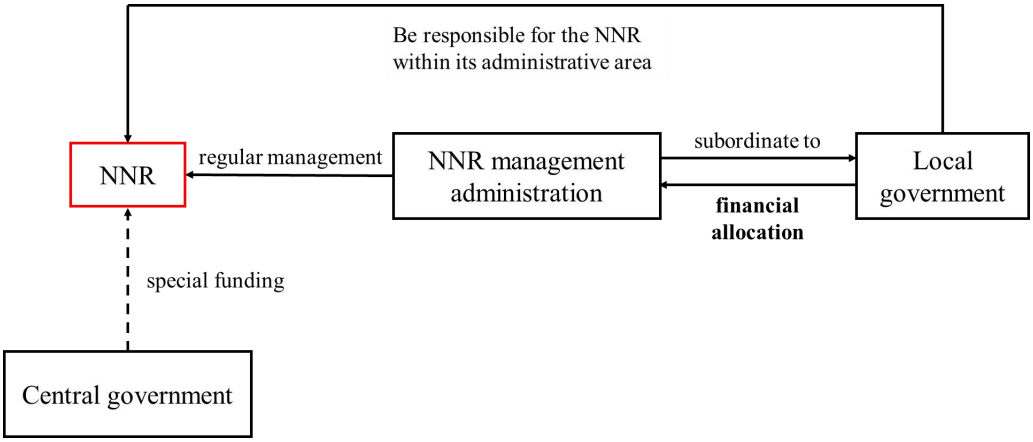


B3. Sources of NNR funds.

Consistent with the materials in Section2 and Appendix B2, The operational oversight and fiscal sustenance of NNRs predominantly fall under the purview of local governments in China. In contrast, the allocation of resources from the central government is relatively negligible. Figure B5 presents the institutional arrangement features pertaining to the funding of NNRs:

Figure B5

The normal structure of NNR fund sources



Here are additional materials that can support that local governments provide the majority of funds to NNRs:

1. Statistical data from National Forestry and Grassland Administration of PRC.

According to China Forestry and Grassland Statistical Yearbook, the total investment in the "Natural Reserve Monitoring and Management" project in 2019 was 1.839 billion yuan RMB, of which the funding from the central government was 0.704 billion yuan RMB, accounting for 38.28% of the total investment. In the subsequent years of 2020, 2021, and 2022, the proportions of central government funding were 46.22%, 38.59%, and 41.88% respectively.

2. Some fragments of a report from "YICAI" magazine in 2019

Based on the interview of the 13th National People's Congress delegate Jianbo Sun by "YICAI" magazine in 2019, the central government's funding allocation for NNRs in China is very limited.

"Nature reserves are public resources of the country, and their cause is a public

welfare undertaking. Ensuring funding is an inevitable requirement for the central government to fulfill its responsibility for the management of nature reserves," said Jianbo Sun. However, in reality, the central government only provides a small amount of funding for NNRs that were originally managed by the forestry system. The central government allocates only 300 million yuan for basic construction and 300 million yuan for capacity-building annually, which can only meet one-third of the needs of the reserves, resulting in a severe lack of conservation funds.

Jianbo Sun summarized the management dilemma of nature reserves in China from five aspects:

(1) The grassroots management force is "weak and incapable." Due to the lack of national investment, some institutions in nature reserves are nominal, with weak functions. In many cases, some nature reserves either have no institutions or have staffing but lack personnel[41]. As a result, the national conservation management policies at the grassroots level suffer significantly by the lack of necessary personnel.

(2) Enforcement and supervision are "well-intentioned but powerless." Due to insufficient funding, conservation management methods are outdated, and there is a severe lack of technical support. Currently, various types of nature reserves in China are still at a primitive stage of "relying on verbal promotion, patrolling on foot, and law enforcement through confrontation." For instance, after marine reserves and marine parks were transferred to the management of the forestry and grassland bureau, Law enforcement officers are no longer allowed to use coast guard or fishery administration vessels. As a result, there is a sense of powerlessness in dealing with illegal fishing and tourism activities within the reserves.

(3) The conservation direction is "contrary to the original intention." In the situation of severe shortage of central and local finances, many regions directly contract out nature reserves to tourism companies, leading to these reserves becoming purely tourist development sites, fundamentally deviating from the original purpose of establishing these reserves.

(4) Infrastructure construction funds are "a drop in the bucket." The central government only allocates 600 million yuan annually for existing 474 national nature reserves, averaging only 1.26 million yuan per reserve. The central government's annual management funds for 244 national scenic spots are only 2 million yuan, averaging less than 10,000 yuan per national scenic spot per year. Moreover, geological parks and marine parks receive no central government funding. Some scenic spots, geological parks, and marine protected areas do not have the funds to build facilities

[41] Personnel means "bianzhi" in Chinese.

such as boundary markers, management stations, and patrol stations.

(5) International exchange and compliance capabilities are “constrained.” China has the most World Natural Heritage Sites and Dual Heritage Sites as well as the most geological parks in the world. However, due to the lack of support for talent development and international exchange funding, out of over 2,100 international personnel working with the United Nations Educational, Scientific and Cultural Organization, only 10 are Chinese. This is incongruent with China’s status as a major country with world heritage sites.

“Increasing central financial support is the fundamental condition for solving the management issues of reserves,” Jianbo Sun told the reporter. He expressed that establishing a system of nature reserves is one of the important measures to realize the national will of ecological civilization construction. It should be a public welfare undertaking primarily under the authority of the central government. It is necessary to quickly increase the intensity of central financial investment to address the long-standing historical issues of insufficient management capacity in nature reserves and other accumulated problems.

Then, how much money is needed to effectively protect these nature reserves and safeguard China’s ecological security bottom line each year?

The research team led by Yan Xie, deputy researcher at the Institute of Zoology of the Chinese Academy of Sciences and the general coordinator of the research group for nature conservation legislation, previously conducted calculations and provided an answer of 26 billion yuan RMB. “Such a trivial investment can effectively protect 17.48% of China’s land and 10% of its marine areas, thus safeguarding the ecological security bottom line of our country,” Yan Xie told the reporter.

3. Financial statements of Authorities of National Nature Reserve: An Example

Some NNR management committees disclosed the subsidies received from higher authorities in their annual financial statements. We found that management committees received either zero or very little in subsidies from higher authorities. For example, the Jinhuacha National Nature Reserve Management Committee, and the Jiuwan Mountain National Nature Reserve Management Committee received zero subsidies in 2022. The Daming Mountain National Nature Reserve Management Committee in Guangxi received only 127,700 yuan in subsidies in 2022.

Table B1

Financial statements of some Management Committees of National Nature Reserve in 2022

Panel A Jinhuacha National Nature Reserve

项目 Item	金额 Amount (10 thousand)
一、一般公共预算财政拨款收入 General Public Budgetary Financial Appropriation Income	2,154.35
二、政府性基金预算财政拨款收入 Government Fund Budgetary Financial Appropriation Income	0.00
三、国有资本经营预算财政拨款收入 State-Owned Capital Operation Budgetary Financial Appropriation Income	0.00
四、上级补助收入 Subsidy Income from Higher Authorities	**0.00**
五、事业收入 Operating Income	0.00
六、经营收入 Business Income	0.00
七、附属单位上缴收入 Income Turned Over by Affiliated Departments	0.00
八、其他收入 Other Income	182.89

Panel B Jiuwan Mountain National Nature Reserve

项目 Item	金额 Amount (10 thousand)
一、一般公共预算财政拨款收入 General Public Budgetary Financial Appropriation Income	2,840.51
二、政府性基金预算财政拨款收入 Government Fund Budgetary Financial Appropriation Income	0.00
三、国有资本经营预算财政拨款收入 State-Owned Capital Operation Budgetary Financial Appropriation Income	0.00

四、上级补助收入 Subsidy Income from Higher Authorities	**0.00**
五、事业收入 Operating Income	0.00
六、经营收入 Business Income	0.00
七、附属单位上缴收入 Income Turned Over by Affiliated Departments	0.00
八、其他收入 Other Income	10.15

Panel C Daming Mountain National Nature Reserve

项目 Item	金额 Amount (10 thousand)
一、一般公共预算财政拨款收入 General Public Budgetary Financial Appropriation Income	9605.15
二、政府性基金预算财政拨款收入 Government Fund Budgetary Financial Appropriation Income)	0.00
三、国有资本经营预算财政拨款收入 State-Owned Capital Operation Budgetary Financial Appropriation Income	0.00
四、上级补助收入 Subsidy Income from Higher Authorities	**12.77**
五、事业收入 Operating Income	0.00
六、经营收入 Business Income	0.00
七、附属单位上缴收入 Income Turned Over by Affiliated Departments	0.00
八、其他收入 Other Income	363.00

B4. Political incentives exerted on local officials by GSA.

In 2018, the main leaders of the governments and forestry departments of 8 cities (prefectures, districts) in Anhui, Chongqing, and Yunnan provinces were summoned by the Ministry of Ecology and Environment (MEE). This was due to serious illegal development and construction issues within 7 nature reserves in their respective jurisdictions. At the end of the meeting, Changgen Liu, one of the officials from the central environmental department, stated, "It is true that there are many historical legacy issues in our country's nature reserves, and these issues are not the fault of those present here. However, at this stage, addressing these problems is indeed the responsibility and obligation of all of you." The summoning of 11 officials at the department level in a single instance was not common in the past and was seen as a strong move by the MEE to address the management of nature reserves. This kind of summoning placed significant political pressure on local officials, urging them to rectify the issues within the nature reserves[42].

In addition, according to the interview in Wang et al. (2023), the requirements from the central government during GSA had also placed notable political incentives on local officials. For example, one Fujian Forest and Grassland Administration (FGA) official described the requirements as follows:

[The GSA team] compared the satellite images to detect which piece of land had changed, sending all these changes as 'issue spots' to us [provincial FGA]. Then we need to figure out why the land is changed and recover it. The GSA team will later sample-check our remedies. If some nature reserves do not resolve these issue spots within a timeline, the managers of the nature reserves may be punished by criticism or even demotion or dismissal.

In addition, GSA had played a significant role in raising awareness of ecological protection among local cadres. As one Fujian FGA official stated:

Handling illegal cases under the GSA has sounded the alarm for many local cadres. Now they all clearly know that the nature reserve authority is very strict, and the land use purpose should not be changed, must not be changed.

[42] See in https://m.thepaper.cn/newsDetail_forward_2611533.

B5. Challenges encountered during the implementation of GSA.

Local officials commonly encountered significant resistance while implementing the rectification work. Wang et al. (2023) highlight the substantial challenges faced by local officials during the enforcement of rectification measures in nature reserves. A significant number of residents had inhabited the area now designated as a nature reserve in Fujian Province, with many living there well before reserve establishment. Given that no unpopulated nature reserves existed in Fujian Province, the strict application of the rule that forbids human activity within the core areas of the reserves seemed impractical. For example, one local official complained:

When the GSA team compared satellite images with the original nature reserve plan, many issue spots emerged. As when the nature reserve was established decades ago, mapping technology was backward, and the boundaries were unclear. Villages, roads, farmland, and commercial forests owned by local farmers were not demarcated from reserve boundaries. Now the GSA team said that 'no human activities are allowed within the reserve. How is it possible to remedy that?

In addition, the long-term lack of adequate management resources compounded the issue. For instance, in Fujian Province, there were two national nature reserves where the management team consists of fewer than ten people responsible for over 10,000 hectares, underscoring the deficiency in both funding and personnel for proper reserve management.

Besides the complaints of local officials, the local residents were resisting the implementation of GSA. Most local people's attitude was clear. one village leader said, "We understand ecological protection, but we need to live." When GSA officials arrived, and the rectification work started, they encountered strong resistance from local villagers. The incentive for local people to go against GSA was the preservation of their livelihoods, and their objective was for things to continue as they were. Conflicts arose when GSA officials visited the "issue spot". One FSA official mentioned that they were blocked by residents on their way to the village and were questioned by local farmers:

You guys came here by car, and you know it is convenient to drive, don't we know that? We [local villagers] raised money and built a road, and the government did not pay one penny. But now you told me that the road is illegal? And ask to demolish it? Is that reasonable?

B6. A case for the Jinyun Mountain NNR: timeline of GSA implementation

In July 2017, the Ministry of Environmental Protection of PRC, later renamed the Ministry of Ecology and Environment (MEE) announced the launch of GSA. GSA is the first nationwide joint initiative by the supervisory authorities, aimed at conducting comprehensive monitoring and inspection of all national nature reserves.

During July 2017 to December 2017, seven ministries jointly organized and executed GSA for NNRs. The MEE utilized various technological tools to support GSA. They issued remote sensing problem lists, collected and compiled public feedback, and organized self-inspections and provincial spot checks, establishing a comprehensive system to address violations and promote timely rectification.

In April 2018, remote sensing monitoring by the MEE revealed that there were over 500 human activity areas, including tourist facilities and industrial land, within the Jinyun Mountain National Nature Reserve in Chongqing City. This encroachment had significantly exacerbated ecological damage issues.

In June 2018, the central government issued an important instruction regarding the Jinyun Mountain NNR, urging local authorities to earnestly carry out rectification measures. Under the political pressure from the central government, the leadership of Chongqing Municipality had attached great importance to the issues within the Jinyun Mountain NNR. Min'er Chen, the secretary of the Chongqing Municipal Committee of CPC, and Liangzhi Tang, the deputy secretary of the Municipal Committee and the Mayor, had visited Jinyun Mountain nine times to direct, research, and supervise the rectification work. The Chongqing government convened 33 meetings to study and deploy comprehensive rectification work and issued the "Comprehensive Plan for Ecological and Environmental Remediation in Jinyun Mountain Nature Reserve."

In August 2018, the Chongqing government demolished an illegally constructed horse racing track located within the Jinyun Mountain NNR.

In September 2018, the MEE summoned the responsible officials of relevant government departments regarding the encroachment and destruction of natural reserves. Officials from Shapingba District, Beibei District, and the Chongqing Forestry Bureau were among those summoned for meeting. The meeting exerted further pressure on officials from these relevant departments, urging them to properly rectify the nature reserve.

On February 11, 2019, the Chongqing government issued the "Guiding Opinions on Implementing Ecological Relocation Pilot Projects in the Jinyun Mountain Nature Reserve," successively implementing relocation pilot projects for the indigenous people within the core and buffer zones of the Jinyun Mountain Nature Reserve.

In June 2019, the Chongqing government launched a comprehensive improvement

project. The project aims to leverage the outstanding natural ecology and landscape of Jinyun Mountain, by restoring wetland hydrology, increasing vegetation coverage, and constructing an ecological system to create a demonstration area for the ecological barrier in the upper reaches of the Yangtze River.

As of April 2020, the Chongqing government had successfully relocated the indigenous people within the NNR, including 442 households totaling 1144 individuals, representing 98.0% and 98.5% of the total households and population slated for relocation, respectively.

In September 2020, the Chongqing government started the Mazhongju Ecological Restoration Project, specifically the “Peng Feng Kan Yun” Scenic Viewing Platform project.

As of May 2021, over the course of three years of comprehensive management, the Beibei District Government (a county-level government under Chongqing Municipality) had cumulatively invested 2.75 billion RMB. This effort had resulted in the resolution of 269 prominent environmental issues in Jinyun Mountain, with the planting of 774,000 trees and shrubs, and the restoration of 450,000 square meters of land for greenery.

During 2021-2022, the Chongqing government remained committed to advancing the implementation of ecological restoration projects within the NNR. The government were dedicated to completing the Overall Plan for the Jinyun Mountain NNR in Chongqing (2021-2030), ensuring a comprehensive and sustainable approach to conservation and restoration. Furthermore, the government were actively working to establish a regular inspection institution specifically tailored to oversee and maintain the integrity of the NNR.

Regular enforcement stage

Wait-and-see stage

- July 2017
  The declaration of the GSA by Ministry of Ecology and Environment (MEE).
- July 2017 ~ Dec 2017
  Seven ministries jointly organized and executed the GSA campaign for NNRs.
- Apr 2018
  Illegal activities were found. The MEE's remote sensing had identified over 500 human activity areas, including tourist facilities and industrial sites, in the Jinyun Mountain NNR.

Accountability and rectification stage

- June 2018
  Central government intervention. The central government issued important instructions, urging local authorities to take serious rectification actions. Then, the Chongqing government issued the "Comprehensive Plan for Ecological and Environmental Remediation in Jinyun Mountain Nature Reserve."
- Aug 2018
  Demolished illegal structures. The Chongqing government demolished illegal structures in a horse farm inside the NNR.
- Sept 2018
  Local government officials are summoned for meeting. The MEE summoned the responsible government departments regarding the encroachment and damage to natural reserves.
- Feb 2019
  Initiation of the relocation of residents. The Chongqing Government initiating the relocation of indigenous residents inside Jinyun Mountain Nature Reserve.
- June 2019
  Start comprehensive improvement project. The comprehensive improvement project of the Jinyun Mountain Nature Reserve in Beibei District was initiated.
- Apr 2020
  The majority of relocation work has been completed. Over 98% of the residents who originally lived within the nature reserve had been relocated. 440 million yuan RMB were used by the local government.
- Sept 2020
  Start Mazhongju Project. Start Mazhongju ecological restoration project inside the NNR.
- May 2021
  2.75 billion yuan in 3 years. As of May 2021, the government of Beibei District (a county-level government under Chongqing Municipality) had invested a total of 2.75 billion yuan in NNR.
- 2021 ~ 2022
  - Continue to promote the implementation of ecological restoration projects inside the NNR.
  - Complete of the Overall Plan for the Jinyun Mountain NNR in Chongqing (2021-2030).
  - Establish the regular inspection institution for nature reserves.