Pricing the Priceless:
The Financing Cost of Biodiversity Conservation*

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Abstract

Biodiversity conservation incurs substantial economic costs. We investigate how financial markets price the risks such costs induce, exploiting the "Green Shield Action," a major regulatory initiative launched in China in 2017 to enforce biodiversity preservation rules in national nature reserves. While improving biodiversity, the initiative led to significant increases in bond yields for municipalities with these reserves, effectively increasing the cost of public capital. The effects are driven by increases in local governments' fiscal risk due to expected increases in transition costs resulting from eradicating illegal economic activities within reserves and additional public spending on biodiversity. Investors show little non-financial consideration towards endeavors counteracting biodiversity loss.

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1 Introduction

The ongoing rate of biodiversity loss underscores the intricate nexus between nature and the global economy (Flammer *et al.*, 2023). Since 1900, 477 vertebrate species have become extinct in the wild, and 30 to 50% of all species are estimated to face the risk of extinction by the middle of this century (Ceballos *et al.*, 2015; Deutz *et al.*, 2020; Jaureguiberry *et al.*, 2022). This reality calls for biodiversity conservation, which carries significant costs. Prior studies have evaluated the direct economic costs of this transition (IPBES, 2019; Deutz *et al.*, 2020) and the asset pricing implications of biodiversity risk (Coqueret *et al.*, 2024; Garel *et al.*, 2024; Giglio *et al.*, 2023, 2024; Xiong, 2023). However, the financing cost of biodiversity conservation and its implications for financial markets remain largely unexplored (Karolyi & Tobin-de la Puente, 2023; Starks, 2023).

We contribute to this literature by presenting new evidence from a major policy for biodiversity conservation in China, the Green Shield Action (GSA). GSA is a national regulatory initiative launched by the central government in 2017 to reinforce the safeguard of national nature reserves (NNRs). NNRs are legally designated areas for biodiversity conservation managed by local governments. In recent decades, many of the local administrations in charge of such reserves failed to fulfill their responsibilities, allowing economic activities such as mining, tourism, and hydropower energy generation to occur within their NNRs. In July 2017, the central government launched GSA to identify such violations. Under GSA, the central government began conducting rigorous investigations and exerting pressure on local authorities to act in response to reported violations.

We focus on the impact of GSA on the pricing of municipal corporate bonds (MCBs). In targeting the protection of nature reserves, the GSA leaves little discretion to local governments in terms of implementation (Wang *et al.*, 2023). Crucially, the funding responsibility of the conservation effort in NNRs largely falls on local governments. This has led to substantial increases in financial pressure for municipalities containing NNRs after the introduction of GSA. Unlike corporations, municipalities cannot change their location to avoid transition and conservation costs. Thus, MCB investors must account for such local risk when valuing these bonds.

Our empirical analysis utilizes three main datasets. First, we manually construct a new dataset that contains the geographical location of all NNRs in China. This allows us to identify municipalities whose boundaries encompass national nature reserves. Second, we utilize data on the issuance and trade information on all MCBs in China from January 2013 to June 2022. To assess the impact of GSA on local conservation efforts, we use satellite remote sensing data, information sourced from government procurement documents, newspaper articles, and bird observation records. These additional data sets provide a multifaceted perspective for ascertaining the mechanisms through which GSA influences public financing costs.

We implement a standard difference-in-differences (DID) empirical strategy. We compare changes in the yield spreads of MCBs of municipalities containing at least one NNR (NNR municipalities) with those of municipalities without NNRs (non-NNR municipalities) around the launch of GSA. We select the third quarter of 2017 – when GSA was launched – as the beginning of the treatment period. We document that, compared to non-NNR municipalities, NNR municipalities experience a 24-basis-point larger increase in their yield spreads following the introduction of GSA. This corresponds to 18% of the in-sample standard deviation (136 basis points). The results are robust to using more flexible measures of treatment intensity (i.e., the area of NNRs), alternative bond spread measures, and data frequencies.

A central challenge with our identification strategy is whether the documented differences in bond yields between NNR and non-NNR municipalities 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. Including controls for bond- and city-level characteristics in our estimating equation leaves the size of the main coefficients stable. 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.

We discuss and test the potential mechanisms behind the impact of GSA on the risk premium demanded by MCB investors. We start by investigating whether expected transition costs can explain the increase in 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 must undertake to comply with GSA. These efforts include closing down illegal economic activities taking place inside NNRs and recovering the corresponding damaged local biodiversity. Utilizing remote sensing data on developed land and nighttime luminosity, we find that a higher presence of human economic activities within NNRs before GSA is associated with a more pronounced pricing effect.

Second, we construct a measure of government expenditure on biodiversity conservation by analyzing the text of local government procurement contracts to identify those associated with nature reserves. We document that, after the implementation of GSA, NNR municipalities experienced a larger increase in the value of procurement contracts associated with nature reserves. These results are consistent with increases in the real costs of biodiversity conservation following GSA.

Third, we study changes in the fiscal position of local governments following GSA. We find a decline in the fiscal surplus of NNR municipalities compared to non-NNR municipalities. The impact of GSA on MCB spreads is greater for municipalities with a heavier initial debt burden and for MCBs with shorter maturity. We consider whether the observed pricing effects could be attributed to an increase in the level of public financing—

to fund the growing spending on biodiversity, local governments only reorganize internal resources, but may 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. Also, the documented change in MCB yields could be driven by an increase in political risk for the local public officials who are now accountable for the implementation of the reform. However, we find no empirical evidence in support of these channels. Borrowing activities of local governments and the turnover of local officials remain stable around GSA.

We also investigate investors' potential non-pecuniary preference for biodiversity (i.e., the so-called "Values" in Starks, 2023). Specifically, if there are a considerable number of "impact investors" who care about biodiversity but are uninformed about the actual conditions of NNRs, then GSA may reveal the poor practices of local officials in the management of reserves. This information may trigger investors to impose an overdue punishment on the securities issued by the responsible authorities. If this mechanism holds, we expect municipalities with higher information asymmetry on NNRs to experience a greater increase in MCB spreads. We compare NNR municipalities to different levels of newspaper coverage related to NNRs but find insignificant heterogeneous effects.

To quantify the real biodiversity benefits of GSA, we collect new data on observed bird species recorded by bird-watching enthusiasts and research observation stations, as well as species richness measures constructed by IUCN Red List. We find that GSA has indeed led to an increase in the number of observed bird species. If investors value the non-pecuniary biodiversity benefits of GSA, then one would expect a lower increase in MCB spreads in municipalities where GSA led to a larger improvement in biodiversity. However, we do not find any evidence of such heterogeneous effects. Although this might just be due to the fact that changes in biodiversity are hard to monitor by investors, the lack of alignment between biodiversity benefits and investors' valuation can hinder biodiversity conservation efforts in general.

Finally, to quantify the aggregate financial cost of the biodiversity transition, we perform a back-of-the-envelope calculation comparing counterfactual annual interest payments inferred from our estimates with actual payments. Our calculation is based on the outstanding debts of Local Government Financing Vehicles (LGFVs) with MCBs from 2013 to 2021.[1] We find that GSA led to aggregate extra interest costs of around 40 billion U.S. dollars from 2018 to 2021. As a reference, Deutz *et al.* (2020) estimates that China would need to spend 45.5 billion dollars per year to protect biodiversity according to its proportion of species in the world. The extra financing costs brought by GSA account for 11.54%, 25.36%, and 47.12% of these estimated direct costs in 2019, 2020, and 2021, respectively.

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

Our paper contributes to the literature on natural capital and biodiversity conservation.[2] The literature has documented the benefits of biodiversity, such as boosting agricultural productivity (Frank *et al.*, 2024), reducing human health risks (Frank & Sudarshan, 2024; Frank, 2021; Keesing & Ostfeld, 2021), and enhancing resilience to climate change and natural disasters (Isbell *et al.*, 2015; Rizzi, 2022; Taylor & Druckenmiller, 2022). However, we still have limited evidence on the economic costs associated with biodiversity conservation. Recent work has documented that conservation efforts may lead to labor market unemployment (Ferris & Frank, 2021) and a decline in the value of resource extraction rights (Bošković & Nøstbakken, 2017). Our paper provides new empirical evidence on the effects of biodiversity conservation on public financing costs in the context of a large government-led conservation effort.

Our paper is also related to the literature on biodiversity and financial markets. Recent work includes Giglio *et al.* (2023, 2024), Garel *et al.* (2024), Coqueret *et al.* (2024), Xin *et al.* (2023), and Xiong (2023), which have developed metrics to characterize the biodiversity risks faced by firms and their risk premia in equity or derivatives markets. We extend the discussion by exploring how the costs of biodiversity conservation are priced in bond markets in a large emerging economy of significant importance for global biodiversity conservation.[3] Unlike other economic effects that often stay local, external validity is not a concern here given the global nature of sustainability issues such as climate change and loss of biodiversity (e.g., Bolton & Kacperczyk, 2023); if anything, studies beyond the settings of developed countries where empirical finance research has focused on prove crucial. Moreover, because most governments do not use equity financing that gives investors an upside in the long run, our findings point to a particular challenge of financing biodiversity conservation via debt markets.

More broadly, our study is related to the growing body of research on sustainability and climate finance (Choi *et al.*, 2020; Engle *et al.*, 2020; Sautner *et al.*, 2023; Ardia *et al.*, 2023; Bolton & Kacperczyk, 2021; Delis *et al.*, 2018; Ilhan *et al.*, 2021; Dang *et al.*, 2023; Seltzer *et al.*, 2022; Hong *et al.*, 2023). Relative to research on climate, which focuses on physical systems, biodiversity research lacks reliable and widely accepted evaluation measures. The monetary value of biodiversity conservation projects is difficult to quantify, and property rights are challenging to define (Karolyi & Tobin-de la Puente, 2023). These characteristics make it difficult to design market-based mechanisms for biodiversity finance that are similar to carbon trading, thus necessitating direct public capital intervention to address market failures related to common goods (Kedward *et al.*, 2022). Therefore, in

[2] Seminal contributions by Weitzman (1992, 1993, 1998) measure the "value of diversity"; Heal (2001) provides an overview of biodiversity's services, and Brock & Xepapadeas (2003) integrate ecological and economic frameworks for valuing biodiversity.

[3] For instance, Egli *et al.* (2018) find that optimizing integrated land use planning for sustainable intensification in ten countries—China, India, the Philippines, Brazil, Australia, Mexico, Indonesia, the Democratic Republic of the Congo, Ecuador, and Vietnam (with a majority being emerging economies)—could prevent an estimated one-third of biodiversity loss by 2040.

biodiversity transition, the role of government is particularly important and the impacts of biodiversity risks on the public sector extend beyond revenue risks and asset value depreciation (Jha *et al.*, 2020; Painter, 2020; Goldsmith-Pinkham *et al.*, 2023; Jerch *et al.*, 2023). Our paper emphasizes that both direct conservation inputs and the resulting effects on the cost of public capital should be considered.

Finally, our paper is related to impact investing. According to Starks (2023), investors may base their decisions on two types of motivations: the pursuit of financial benefits ("value" motivation) and non-pecuniary preferences ("values" motivation). Although some investors are willing to sacrifice certain financial returns for sustainable development or long-term gains (Baker *et al.*, 2022; Barber *et al.*, 2021; Feldhütter *et al.*, 2024), and previous studies have documented a positive link between eco-friendly behavior and stock market outcomes (e.g., Krüger, 2015; Flammer, 2021), this is not universally the case. In fact, numerous studies have found that some investors prefer sustainable projects because they offer higher returns or lower risks (Giglio *et al.*, 2025; Dimson *et al.*, 2015, 2021; Krueger *et al.*, 2020; Starks *et al.*, 2023; Hoepner *et al.*, 2024). Our analysis indicates that, although GSA has led to actual improvements in biodiversity, financial consideration related to the conservation dominates investors' thinking. In important economies like China, the influence of socially responsible investment missions that focus on the intrinsic value of biodiversity may not yet be large enough to determine the equilibrium market price.

2 Institutional Background

2.1 Nature Reserves in China

With its diverse climate and large number of recorded known species — 138,293, 6.4% of the total number recorded worldwide — China is among the most biologically diverse countries in the world.[4] For example, China is the third country by number of vascular plant species, after only Brazil and Colombia. This wealth of biodiversity underscores its vital importance for the global ecosystem.

To protect its natural capital, China has designed an extensive network of nature reserves — land, inland waters, or seas containing representative natural ecosystems, habitats for rare and endangered wild species, or natural relics with special significance.[5] Among them, national nature reserves have the most extensive regulatory oversight and strictest legal provisions compared with other provincial, municipal, and county nature

[4] See, e.g., http://www.sp2000.org.cn/CoLChina and https://www.iucnredlist.org/resources/summary-statistics.

[5] Our definition of nature reserves follows the law and regulation of the People's Republic of China, which govern 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. In particular, the regulation stipulates that nature reserves are for biodiversity preservation.

reserves. Correspondingly, the regulations stipulate that only reserves "holding general significance domestically and internationally, exerting remarkable international scientific influence, or possessing extraordinary research value" can be designated as NNRs.

The designation of NNRs is solely based on the long-term endowment of natural resources, without considering contemporaneous local economic and fiscal conditions of the regions where the reserves are located.[6] According to regulations, the local government should first submit a formal application to the administrative authority of NNRs under the State Council. The central review committee for NNRs is responsible for the evaluation process. After receiving a report on the biological situation of the candidate reserve, the committee members vote. For an NNR to be eligible for State Council approval, it must receive a two-thirds majority vote. Evaluation criteria include fragility, diversity, endangered status, and scientific value of the natural resources of the reserve. 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 of nature reserves in China over time.[7]

Following the establishment of an NNR, the local governments are responsible for managing, supervising, and conserving NNRs within their jurisdictions. Each NNR is typically governed by a dedicated committee that manages its operations. This committee functions as an administrative entity under the local government's authority, and it is financed by local government funds.[8] NNRs also receive funding from the central government. However, this central funding is usually limited. For example, Jianbo Sun, a deputy 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 (about 80 million USD). This breaks down to an average of just 1.26 million yuan (about 170 thousand USD) for each reserve. Given limited central funding, local governments bear most of the financial responsibility for maintaining NNRs.[9]

As Figure 1 shows, the three decades between 1980 and 2010 have seen a large increase in the creation of new nature reserves, whose number has stabilized during the last decade. In the early decades, the effectiveness of nature reserves in protecting biodiversity fell short of expectations. Local officials prioritized economic development over environmental

[6] Evaluation criteria for NNRs are available at https://www.mee.gov.cn/stbh/zrbhq/gjjzrbhqps/201605/t20160522_342427.shtml.

[7] 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. Toward the end of the 20th century, China also 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. After 2010, the rate of growth of nature reserved slowed. Currently, there are over 2,700 nature reserves (around one-sixth of which are NNRs), covering more than 140 million hectares.

[8] See Appendix B.2 for more details regarding the institutional structure arrangement of NNRs.

[9] See Appendix B.3 for more details on funding sources for nature reserves.

issues (Guan *et al.*, 2010; Liu, 2010), resulting in the deterioration of numerous reserves. A prime example is the Qilian Mountain NNR in Gansu Province, where exploration and mining activities caused substantial damage to local vegetation, soil erosion, and surface subsidence. For instance, 14 mining and exploration projects within this area were found to be unauthorized, with 3 of these instances located within the core area of the NNR, where in principle no individual is allowed to enter and no economic activity can be carried out. In addition, over 30 mining projects were concealed, and over 40 hydropower plants were constructed illegally.[10] Following the "Qilian Mountain Incident," the Ministry of Environmental Protection of China announced plans to inspect environmental issues in all national nature reserves from July to December 2017. The initiative was named the Green Shield Action (GSA).

2.2 Green Shield Action

Launched in July 2017, GSA is a major regulatory effort by the central government to enforce biodiversity conservation in all 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 clear change in China's effort to regulate and supervise NNRs, and reflects policymakers' commitment to improving biodiversity conservation.

In practice, GSA is a special supervision campaign implemented via investigation teams in charge of on-site inspections of national nature reserves. Investigation teams use various technologies – including high-resolution remote sensing – to inspect NNRs, identify illegal activities, and report to the central government. Following these reports, the central government urges local administrations to investigate the uncovered violations and rectify them. Every local government unit in charge of an NNR must also create and execute a detailed work plan that aligns with the guidelines set by GSA. This plan includes regular inspections. Through these approaches, the central government placed significant political incentives on local officials to ensure that illicit activities are curbed.[11]

GSA implementation encountered local resistance. First, several NNRs are severely understaffed, making it difficult to comply with requests from the central government. Moreover, prior to the designation of an area as an NNR, there was already a large number of residents living within these regions. Relocating residents and demolishing existing structures is extremely challenging. Finally, local governments also need to

[10] The central government conducted a special investigation into the Qilian Mountain National Nature Reserve, verified the ecological damage, held local officials and state-owned enterprises accountable, and made a public statement (see http://www.gov.cn/xinwen/2017-07/20/content_5212107.htm).
[11] See Appendix B.4 for further details regarding the political incentives faced by local officials.

undertake ecological restoration projects within the reserves and allocate substantial funds to enhance the supervision of these areas and improve their operations.[12]

An illustrative case in this respect is the relocation of the Jinyun Mountain Nature Reserve in Chongqing. In principle, 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, the reserve had nearly 9,000 residents living within its boundaries. This imposed a critical burden on local authorities that had to evacuate the area to meet GSA's requirements. Specifically, the Beibei District Government (a subordinate government of the Chongqing Municipal Government), which oversees the Jinyun Mountain Reserve, invested over 440 million yuan in the relocation effort in 2019, despite its fiscal revenue being 3 billion yuan in that year. Furthermore, GSA stipulates that the Chongqing Government must demolish all illegal buildings within the reserve, including housing, rural tourism facilities, hotels, and horse farms. Such requirements further compound the economic costs.[13]

After the first phase of the GSA in 2017, the central government continued its efforts in subsequent years by 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 NNR shown in Figure A1). By perpetuating these actions after 2017, the central government solidifies the expectations regarding its commitment to protect biodiversity and nature reserves, thus shaping the financial market's perception of the 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,

[12] See Appendix B.5 for further details regarding the challenges encountered during GSA.

[13] These economic costs at least include: (1) The direct costs of demolition: hiring contractors, machinery, and workforce to carry out the destruction of the buildings. (2) Relocation costs: providing compensation or support for those who are displaced by the demolition. (3) Potential legal and administrative costs: arising from disputes or negotiations with property owners. See Appendix B.6 for further details regarding the initiatives undertaken by the Chongqing government.

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. In terms of financing, 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.[14] Subsequently, both the number and total liability of LGFVs experienced a significant surge, which raised concerns about the default risks of municipalities.[15] 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; Gao *et al.*, 2021), where "corporate" reflects the fact that LGFVs have the same legal status as other regular corporations nominally, and "municipal" indicates the exclusive implicit guarantee from the local government.[16] 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. 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.[17] In addition, the vast majority of MCB issuers are LGFVs owned by local governments below the province level, providing us with variation in bond prices

[14] 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).

[15] 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%. In addition, 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. Gao *et al.* (2021) show that some LGFVs led to actual defaults on loans, suggesting that municipalities indeed have considerable credit risk that could be priced in MCB yields, consistent with Ang *et al.* (2023).

[16] 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.*, 2023), and "urban construction and investment bonds" (Liu *et al.*, 2017), and "LGFV bonds" (Fan *et al.*, 2022).

[17] 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.

at a fine geographical level.[18]

Importantly, the market holds faith in municipalities' implicit guarantee for LGFVs and thereby prices credit risk of local governments when investing in MCBs after 2015 (Liu *et al.*, 2017). In general, MCBs' credit rating reports typically consider local governments' fiscal conditions 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.[19] The rationale behind this is that since cities do not have discretion on issuing municipal bonds directly, their LGFVs still rely on financial support from local governments. Governments at different levels have repeatedly defused the debt repayment crisis of LGFVs, and there have been no real defaults on MCBs so far.[20] Given this institutional setting, the price of MCB is likely to reflect the market views on local public financing costs during our sample period.

3 Data Description

3.1 National Nature Reserves

We collect the list of nature reserves and zoning images of NNRs from the Ministry of Ecology and Environment of the People's Republic of China (PRC). By aligning zoning images of NNRs with the standard administrative map of China, we construct a dataset that includes information on NNR 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 the reserve and administration levels. Furthermore, we can construct some novel metrics (e.g., human economic activities within NNRs) after merging the data with other geographical datasets.

3.2 Data on Municipal Corporate Bonds

We obtain municipal corporate bond data from Wind Information Co. (WIND), a leading financial data vendor in China and the most widely used MCB database for our sample period. WIND provides data on: (1) The 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. (3) Information

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

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

[20] In contrast, some credit bonds issued by private-owned and non-LGFV state-owned enterprises have defaulted (Geng & Pan, 2024).

on each MCB issuer, including location, affiliation, and bond issuance. (4) Daily yield curve of Treasury bond and the Chinese Development Bank (CDB) bond.[21]

Following Geng & Pan (2024), we study MCB yields around GSA at the quarterly frequency using the last daily transaction price of the quarter for each MCB.[22] To proxy for the risk premiums that investors demand for investing in bonds, we use the CDB bond as the risk-free benchmark and calculate MCB spreads as the difference between the MCB yield and CDB yield on the same day and of the same maturity (Chen *et al.*, 2023; Geng & Pan, 2024).[23] Treasury yields are employed in robustness checks.

3.3 Sample and Summary Statistics

Our sample covers the period from January 1, 2013, to June 30, 2022.[24] 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- 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. City-level characteristics include baseline variables capturing the economic and social conditions of a city collected from the National Bureau of Statistics and local statistical yearbooks in China in 2013. Table A1 provides the details of all the variable definitions. We winsorize MCB spreads and city-level continuous variables at 0.5% on each tail of the distribution.

Table 1 shows that about 51% of MCB observations are from NNR municipalities, with about 63% of the observations occurring after the launch of GSA. MCBs in our sample have an average residual maturity of 3.83 years and tend to be traded mostly in the interbank (over-the-counter) 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 below 3, which is higher than non-MCB corporate bonds (Ding *et al.*, 2022; Geng & Pan, 2024), reflecting the "municipal" nature of MCBs. Figure 3 illustrates the unconditional dynamic of the average MCB spreads over time. The

[21] We restrict the bond 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 insufficient information disclosure.

[22] WIND reports historical transaction information in the daily frequency, with price-related metrics weighted by the volume. In addition, "trading day" refers to the days on which real transactions took place on the corresponding bond, excluding the days on which investors could trade but did not.

[23] 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, making the yield of this highly liquid security a good proxy for the risk-free rate in the context of our study.

[24] 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, also referred to as CCP) 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.

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.

4 Empirical Strategy and Findings

4.1 Empirical Strategy and Main Results

Our baseline empirical strategy is a standard difference-in-differences approach that compares the relative changes in the MCB spreads in NNR municipalities and non-NNR municipalities around the introduction of GSA. The specification takes the following form:

$$Spread_{bict} = \delta_{ic} + \delta_t + \beta NNR_c \times Post_t + \theta X_c' \times Post_t + X_{bict}'\gamma + \varepsilon_{bict}, \tag{1}$$

where b indexes bonds, i indexes issuers, c indexes cities, and t indexes year-quarters. The dependent variable, $Spread_{bict}$, is the spread of bond b issued by issuer i, located in city c, and traded in year-quarter t. NNR_c is a dummy variable that equals one if a city geographically intersects with an NNR and zero otherwise.[25] $Post_t$ is a dummy variable that equals one for the period after the introduction of GSA (i.e., from the third quarter of 2017 to the second quarter of 2022). We also include bond issuer fixed effects and year-quarter fixed effects. X_c denotes city-level control variables. Specifically, we interact the pre-determined city-level variables observed in 2013 with $Post_t$ to control for differential trends across cities with different initial characteristics. We control for time-varying bond-level characteristics (X_{bict}) and cluster standard errors at the city level.

One obvious concern when estimating Equation (1) is that NNR and non-NNR municipalities might differ along other dimensions, and, in particular, dimensions that could affect the evolution of their bond prices in the period around the launch of GSA. To test this concern, we collect data on city-level baseline characteristics from the National Bureau of Statistics and local statistical yearbooks and compare NNR and non-NNR municipalities across a set of observable characteristics including measures of local economic development (log GDP per capita, GDP share of the tertiary sector, log nightlight intensity, log average housing prices, urbanization rate, share of adults with at least high-school education), size (log population and log GDP) and the fiscal position of local governments. We compare NNR and non-NNR municipalities along these characteristics both in lev-

[25] 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. In addition, 2 of non-NNR municipalities established national parks in 2021. 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 establishment of these NNRs. To ensure the validity of our empirical identification, we exclude all 24 cities where the number of nature reserves at national level or above changed after GSA. Thus, the presence of NNRs are completely pre-determined in our sample.

els (at the beginning of our sample period) and in changes (between 2013 and 2016, in the period before the introduction of GSA). The results of the balance test are reported in Table 2. As shown, NNR and non-NNR municipalities are comparable in 21 out of 24 observable characteristics in the period before the introduction of GSA. Statistically significant differences emerge in terms of average annual GDP growth rate in the pre period, with NNR municipalities growing on average 0.5 percentage points slower than non-NNR municipalities. This corresponds to 5% of the average growth, as average local GDP growth was 10.2 p.p. for NNR municipalities and 10.7 p.p. for non-NNR municipalities. We also find small but significant differences in average growth in log nightlight intensity (2.3% higher for NNR municipalities), and population growth (1.3% lower for NNR municipalities). In the empirical analysis we control for municipality characteristics and show that magnitudes of the main effects of GSA on spreads remain stable when including such controls.

Table 3 reports the baseline estimates for Equation (1). Column (1) includes issuer and time fixed effects to capture time-invariant city and issuer characteristics, as well as common time shocks. In Columns (2)-(4), we augment the specification with bond- and city-level controls. The point estimates across all specifications are positive and statistically significant at standard levels. The estimates remain stable in magnitude when including controls, consistently with the balance table results. In terms of magnitude, the estimates in Column (4) indicate that NNR municipalities experienced a larger increase in MCB spreads of around 23.7 basis points following GSA compared with non-NNR municipalities. This effect corresponds to a 12% increase from the sample mean (197 basis points) and a 17.4% increase from the sample standard deviation (136 basis points). These findings are consistent with the notion that the costs brought about by GSA are priced in the MCB market.

To investigate the potential role of dynamic confounders, we estimate a period-by-period specification of the following form:

$$Spread_{bict} = \sum_t \beta_t NNR_c \times q_t + \delta_{ic} + \delta_t + \theta X_c' \times Post_t + X_{bict}'\gamma + \varepsilon_{bict}, \tag{2}$$

where all variables are defined as in Equation (1). The coefficients β_t capture the differences between the treatment and control groups in each quarter between 2013q1 and 2022q2.

Figure 4 plots the estimates of Equation (2) and their 95% confidence intervals. The conditional difference between NNR and non-NNR municipalities is small in magnitude and non-statistically significant before the introduction of GSA. This is consistent with the parallel trend assumption. The difference increases in the post-GSA period starting about one year after the introduction of GSA. This delay can be prima facie puzzling as one would expect bond prices to respond immediately when the policy is announced.

There are two factors potentially contributing to the lagged effects of GSA on spreads. First, the central government inspected NNRs between late 2017 and early 2018, and only after that – and violations identified and punished – did local governments start planning serious responses and announced their response plans. It is plausible that, following the announcement of GSA, investors did not have right at the announcement the information on the extent of the uncovered violations or the financial costs necessary to address them.

Second, it is plausible that both local officials and investors were initially uncertain about the true commitment of the central government to the reform (Wang *et al.*, 2023). Each year, local officials receive multiple campaign-style requests from Beijing, only a few of which represent true priorities for the central government. As enforcement intensified and annual inspections became the norm, it became evident that compliance with this policy was expected. This shift from campaign-style request to serious enforcement could have led investors to only gradually recognize that the exposed local governments would incur significant biodiversity transition costs. We further discuss the timing of the documented effects in Appendix B.6 using a case study.

Figure 4 shows that the gap in the MCB spreads between NNR municipalities and non-NNR municipalities was not a temporary increase followed by a decline, but rather a sustained rise. This pattern aligns with the features of GSA enforcement described above. Inspections on NNRs started in 2017 and were repeated annually in subsequent years. Under such a regular supervisory arrangement, it was difficult for local officials to undertake only temporary solutions, and the true magnitude of the necessary ecological restoration projects became more and more clear over time. In this sense, the process of implementation of GSA guidelines by local governments was not immediate but rather gradual and progressive. Appendix B.6 presents a detailed case in which a local government adopted a phased investment plan following the GSA.

4.2 Robustness Tests

We test the robustness of the baseline estimates to a range of alternative specifications. First, we examine alternative measures of treatment intensity. Our baseline specification uses a binary treatment variable. In this section, we use the proportion of NNRs within the boundaries of a municipality, which captures continuous variations in pressure on municipalities to manage NNRs. Table A2 and Panel A of Figure A2 report the results obtained by replacing the binary variable with alternative measures. Using more flexible measures of exposure to GSA does not alter the baseline findings.

Second, in Table A3 and Panel B-H of Figure A2, we report the results of alternative measures of bond spreads. Specifically, we utilize the quarterly median of spreads, the quarterly mean of spreads, quarterly trading-volume-weighted average spreads, and measures of spread obtained replacing the risk-free benchmark with China's Treasury yields. All results are robust to using these alternative measures of the outcome.

Third, we examine the robustness of the main results to using alternative data frequency for MCBs and the primary bond issuance market data. The corresponding sampling processes are the same as the quarterly secondary market datasets in the baseline specification. The results are reported in Table A4 and Figure A3 in the order of monthly frequency, semi-annual frequency, annual frequency, and the offering sample. Point estimates remain significant regardless of the data frequency used.[26]

4.3 Placebo Test Using Other Nature Reserves

To provide additional evidence that the documented effects are indeed driven by the differential impact of GSA on cities with national nature reserves, we present a placebo test in which we study the differential impact of GSA on cities with nature reserves other than national ones. Recall that national nature reserves are only one type of nature reserves in China, and other nature reserves at the province, municipality, and county level exist in many areas of the country. This analysis also assuages the potential concern that our results reflect the impact of other features of nature reserve during this period. For example, the presence of nature reserves might constrain local economic development via restricting urbanization and limiting a region's fiscal revenue streams for servicing public debts.

We collect data on nature reserves at levels lower than the national level, including provincial, municipal, and county levels. Similar to NNRs, lower-level reserves may also restrict business in the way that hinders land use for urban exploitation. 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 (approximately fivefold), it is also less likely that local officials took proactive actions to rectify issues in lower-level reserves.[27]

We augment Equation (1) with dummies for *Provincial NR*, *Municipal NR*, and *County NR*, where each equals one if the administrative boundaries of each unit intersect with the corresponding type of reserves and zero otherwise, and then interact them with *Post*. Table 4 presents the results: Variation in non-NNR reserves has no additional effect on bond spreads once NNRs are considered. Overall, the findings support the interpretation that the documented effects are driven by GSA and not by dynamic confounders related

[26] Table A5 reports additional robustness tests in which we estimate our baseline specification using alternative samples of NNR and non-NNR municipalities. More specifically, we show that results are robust to: (i) excluding NNR municipalities with the largest national nature reserves in the country, (ii) only using non-NNR municipalities adjacent to an NNR municipality as control group, (iii) only using non-NNR municipalities within a 50 km radius from an NNR municipality, and (iv) using the intersection set of samples from restrictions (i) to (iii).

[27] We should mention that, in practice, GSA occasionally extended beyond NNRs in certain years. However, inspections for non-NNR reserves were often one-off without consistent enforcement efforts in subsequent years. Moreover, according to official statements from the central government, GSA supervision should focus on NNRs. Note that enforcement efforts outside NNR municipalities would, if anything, bias against our estimates.

to other regional attributes associated with the presence of nature reserves.

4.4 Contemporaneous Policy Shocks

We also investigate whether other events related to environmental issues occurring during the same period could affect the MCB market. Two most prominent policies initiated by the central government around the introduction of GSA are: (1) the "Central Inspection on Environmental Protection" and (2) the "Nationwide Campaign to Prevent and Control Pollution." We describe the institutional background next.

Central Inspection on Environmental Protection (CIEP). This initiative was approved by the central government in July 2015 and launched in 2016, and had the objective to inspect and improve environmental conditions in each province.[28] An essential aspect of this initiative was the establishment of a new mechanism for 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.

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.[29] The plan aimed at improving the country's environmental quality by reducing the emissions of major pollutants. The plan targeted pollution in air, water, and land, setting specific goals to be achieved by the end of 2020. More specifically, 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 timing of these policies partly overlaps with the launch of GSA in the second half of 2017. All these policies target environmental issues. CIEP and NBPCP mainly focus on overall environmental risk and pollution activities, whereas GSA concentrates on biodiversity issues, particularly those within NNRs.

[28] 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/).

[29] 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).

To disentangle the impact of GSA from other contemporaneous and related policies, we construct measures of exposure to such policies and include them as controls in our estimation. In Table A6, we measure the impact of CIEP by using four indicators: (1) *In the 1st round*, a dummy variable that equals one for province-quarters in the first round of CIEP investigations; (2) *In the 2nd round*, a dummy variable that equals one for province-quarters in the second round of CIEP investigations; (3) *After the 1st round*, a dummy variable that equals one for provinces investigated in the first round after the first quarter of investigation; (4) *After the 2nd round* a dummy variable that equals one for provinces investigated in the second round after the first quarter of investigation. Overall, we find that after the first round of CIEP, MCB spreads rise more for bonds originating in investigated provinces. However, the coefficients capturing the impact of GSA remain stable in magnitude and statistically significant.

Table A7 includes measures of exposure to NBPCP. 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: the Air Quality Index, industrial sulfur dioxide emissions, industrial wastewater emissions, and industrial dust emissions. The Air Quality Index, as disclosed by the Ministry of Ecology and Environment, is a composite index weighted by the 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 $PostNBPCP_t$, a dummy variable that equals one if the first quarter of 2018 and zero otherwise, and then add interaction terms into our baseline specification. The results indicate that initially more polluted cities (as measured by sulfur dioxide emissions in particular) indeed experienced a higher increase in bond yields after the launch of NBPCP. Still, this seems an independent effect from that of GSA, as the coefficients capturing the impact of GSA remain stable in magnitude and statistically significant.

Macro dynamics of the Chinese bond market. NNR municipalities could also have been more exposed to other contemporaneous shocks facing the Chinese credit and bond market which underwent several regulatory changes during our sample period following an increase in default events. These changes included a forceful push for a more efficient bankruptcy regime (Li & Ponticelli, 2022), and an intensified scrutiny of risky financing activities, in particular the 2018 New Regulations on Asset Management introduced to contain the growth of the shadow banking industry. As documented in Geng & Pan (2024), the New Regulations led to a substantial increase in the SOE premium – i.e. the difference in spreads between bonds issued by non-SOE vs SOE. These events are unlikely to have any significant confounding effects in our analysis. First, all bonds in our

sample are issued by local governments, which are SOEs. Second, we conduct a robustness test in which we restrict our analysis to MCBs with AAA-rating, the top grade in the Chinese bond market, for which default was not a concern. The working assumption of this exercise is that bonds with the same top-notch rating should be similarly affected by contemporaneous reforms aimed at reducing systematic risk in the bond market. This robustness test is reported in Table A8. The results obtained with the sub-sample of AAA-rated bonds are smaller in magnitude relative to the full-sample results (0.25 vs 0.19), but remain close to 20 basis points and statistically significant.

5 Mechanisms

The GSA initiative imposed on local governments to relocate or dismantle unauthorized activities (e.g., mining, power generation, tourism) established within NNRs, leading to a possible decline in economic outputs and public revenue sources. In addition, 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. Because local governments were the main cost bearers of this reform, the overall biodiversity transition cost therefore is expected to be factored into the MCB pricing. Next, we present findings of heterogeneous effects that provide suggestive evidence favoring this mechanism. We also discuss alternative explanations for the influence of GSA on the financing activities of local governments.

5.1 Pre-existing Economic Activity within NNRs

For the implementation and assessment of GSA, the primary regulatory focus is the existence of unauthorized economic activities within the NNRs. Thus, cities with more economic activities within NNRs before the introduction of GSA are likely to face greater pressures for transition, and thus a larger increase in MCB spreads. We test this mechanism using two proxies for pre-existing human activity: the level of developed land and nightlight luminosity within NNRs.

Developed land within NNRs. To identify developed land, we use remote sensing data from the MODIS-IGBP program, which classifies land cover types into forest, grassland, farmland, wetland, urban built-up land, water bodies, and glaciers. We use urban built-up land and farmland to capture developed land within NNRs.

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. Panel A of Figure 5 illustrates the unconditional dynamics in MCB spreads over time for these three categories. In the pre-GSA period, the trends of MCB

spreads across all three groups are close to each other. However, following GSA, MCB spreads began to diverge. NNR municipalities with the largest developed land within NNRs experienced the greatest surge in MCB spreads, followed by NNR municipalities with less developed land within NNRs, and then non-NNR municipalities. This pattern is consistent with the idea that GSA imposed a more significant impact on cities with larger economic activities within NNRs.

Table 5 reports a formal test of these heterogeneous effects by augmenting Equation (1) with a triple interaction of $NNR \times Post$ with a dummy capturing the top quartile of economic activity within NNRs, plus the additional required terms of the triple-difference model (omitted from the table).[30] Column (1)-(2) show that the estimated coefficients of the triple interaction term are positive, statistically significant, and larger in magnitude than the single interaction $NNR \times Post$. This indicates that NNR municipalities with larger pre-existing developed areas within NNRs experienced a greater impact from GSA. This finding aligns with the notion that cities with more economic activities within NNRs before GSA were more likely to face increased public financing costs, since the market concerns more about the anticipated burden of local governments on biodiversity conservation in these regions.

Nighttime luminosity within NNRs. We also utilize nighttime luminosity as an alternative measure for human economic activities.[31] 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. Panel B of Figure 5 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.

[30] As standard in the triple-difference approach, we include the triple interaction term, three dual interaction terms, and three single terms in the regression in Equation (1) and all heterogeneity tests, with some potentially absorbed by fixed effects.

[31] 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.

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. We have introduced examples of how local governments governed NNRs following GSA in Section 2.2. We now quantify the impact of GSA on spending in biodiversity conservation.

The main challenge with estimating these effects is the lack of available data on the exact allocation of fiscal resources across different projects. In particular, we cannot disaggregate specific portions of the local government budget dedicated to biodiversity conservation, especially when it comes to general items such as salaries of civil servants responsible for nature reserves, compensation for resettlement of indigenous communities and businesses, and other associated taxes. Despite the difficulty in precisely identifying the amount paid by municipalities to rectify violations identified by GSA, we estimate the spending via public procurement contracts, which are publicly disclosed and have been used in prior studies (Beraja *et al.*, 2023). These contracts provide insights into the *direct* public investments in protecting biodiversity, which we can assume to co-move with the aforementioned indirect fiscal parts such as salaries and costs associated with relocation.

Identifying NNR contracts. Data on public procurement contracts are sourced from the China Government Procurement website, maintained by the Ministry of Finance. We define NNR contracts as the ones explicitly mentioning the name of an NNR and the term "reserve" (translated as "baohuqu" in Chinese). This is achieved via 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.[32] Next, we manually obtain the amounts for each contract. Out of 2,682 NNR contracts, 2,635 had information on recorded amounts.

Analyzing NNR contracts. According to the textual analysis explained above, the purchasers in NNR contracts 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 expenses, and they indeed have a government procurement amount of zero for all years in our datasets. Therefore, we cannot conduct a standard DID estimation. Instead, we directly aggregate all contract amounts by year for the unconditional trend.

Figure 6 illustrates the changes in the proportion of the total pecuniary value of NNR contracts relative to that of all public procurement contracts in China. In the two years

[32] We provide three examples of NNR contracts in Appendix B.1.

prior to the implementation of GSA (i.e., 2015 and 2016), the share of NNR contracts remained relatively stable. However, following GSA, the proportion of NNR contracts gradually increased year by year, reaching around 0.03% in 2021, about 2.3 times larger compared to the pre-GSA period. This gradual increase trend is also consistent with the bond 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. As GSA gradually became a regular regime rather than a campaign-style regulatory measure after 2018, and as local governments gradually carried out reification and monitoring work on NNRs, NNR contracts increased. Overall, the evidence that emerges by analyzing government procurement contracts shows a significant rise in specific parts of fiscal spending associated with biodiversity preservation after the introduction of GSA. This 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 further corroborate the channel, we also examine whether the GSA-driven transition costs exacerbated the local public creditworthiness. In practice, Chinese local governments have seldom issued special financing instruments with clearly defined sources of repayment funds for nature reserves. Instead, general fiscal budgets account for most investments in biodiversity. In our sample, no MCB is issued explicitely for biodiversity conservation. Thus, MCB investors may pay exclusive attention to the overall credit condition of the city government behind the MCB.

Local fiscal conditions. We start by examining whether GSA worsened local fiscal conditions. We calculate local fiscal deficit as the difference between fiscal expenditure and revenue, normalized by fiscal revenue. Greater government deficits typically indicate a poorer capacity for public debt repayment. We construct a city-year panel for the period 2013-2021 and test the effects of GSA on local fiscal deficit. We include year and city fixed effects, as well as baseline city-level controls. Panel A of Table 6 reports the results. The difference between NNR municipalities and non-NNR municipalities in terms of fiscal deficits significantly increased, suggesting that local fiscal conditions deteriorated following GSA.[33]

Local public debt burden. 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 expected costs to comply with GSA, cities with higher

[33] We calculate fiscal deficits following Connolly (2018) and Bhambhwani *et al.* (2021) and verify in unreported tests the robustness to alternative specifications.

(ex-ante) public debt burdens are more likely to face financial distress and challenges in servicing their bonds. Conversely, cities with low public debt burdens may still possess sufficient funds to safeguard the bondholders' interests. Therefore, in terms of pricing, MCB spreads of the former regions would increase more than those of the latter.

We construct two measures of the local public debt burden. In China, all entities requesting authorization to issue a corporate bond in a given year are required to disclose their liabilities for the current year and (at least) the three previous years. In addition, during the outstanding period of MCBs, the issuer should also publicly reveal its liability terms on a regular basis. Following Huang *et al.* (2020), we perform 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. The city-year aggregate measures are then divided by the corresponding city's GDP in that year. We define a 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 presents the estimates from fully interacted models which include the interaction of each of the two measures of *High debt burden* with our baseline treatment indicator. The coefficients of the triple interaction term are positive, precisely estimated, and larger in magnitude than the interaction between NNR municipalities and the Post-GSA dummy. This indicates that the effect of GSA on MCB spreads is significantly larger for cities with high initial levels of debt burden. This result further corroborates the notion that there is a concern about the heightened risk of a MCB default from MCB investors following GSA.

Bond term structure. The recovery of biodiversity within NNRs and the generation of its sustained social benefits are likely to necessitate a long-time horizon. However, the transition costs associated with GSA already emerge 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.

To explore this heterogeneity in the bond term structure, we examine the effects of GSA on MCB spreads across different levels of bond time to maturity. The term structure cutoff is set as 3 years or 4 years depending on the test. 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 shows that both long-term and short-term MCBs are impacted by GSA, although the effect is larger for short-term bonds.

5.4 Alternative Explanations for Public Financing Activities

Increase demand for financing by local governments. An alternative channel through which GSA could contribute to the widening of the MCB spreads is by exerting greater upward pressure on the demand curve of NNR municipalities. We examine the impact of GSA on the amount of local public financing based on the specification in Panel A of Table 6. Table A9 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 debt. The latter two metrics are measured in a way consistent with the methodology in Section 5.3. We find noisy and non-significant effects on outcomes capturing new 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 capital due to concerns about the creditworthiness of the NNR municipalities. The latter effect might have played a role in determining the amount of financing available to these municipalities, driving 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 (the ex-post perspective) and change the promotion incentive for officials (the ex-ante perspective). 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, received a severe warning within the party, which primarily meant 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 some MCB investors' perspective, 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 mechanism, 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 city-year-level specification in Panel A of Table 6, we find no significant effects of GSA on local political turnover (Panel A of Table A10). We also employ a triple difference specification to study whether the impact of GSA is different during the first two complete years of the leading official's term. Prior studies reveal that officials in the early stages of their term (i.e., the first two years) tend to have weaker political incentives, compared with their more established counterparts (Buntaine *et al.*, 2024). 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 Panel B of Table A10, we do not observe significant heterogeneity across different stages of officials' tenures. Overall, these findings suggest that the potential increase in local political risk is unlikely to be driving the pricing effect of GSA in the MCB market.

6 Biodiversity Improvement, Investor Valuation, and Policy

The preceding discussion has focused on the negative financial impact of GSA. How about its biodiversity impact? Has GSA merely raised concerns or genuinely improved local biodiversity as intended by Beijing? Either way, do bond investors think about biodiversity at all? We discuss and empirically investigate these questions in what follows.

6.1 Impact of GSA on Biodiversity

Because the observation of biological systems is more complicated than physical systems, there have been no reliable and widely accepted metrics to measure the performance of biodiversity finance (Karolyi & Tobin-de la Puente, 2023). Nor are there currently complete panel statistics on various species at a fine geographical level in China. As a proxy for biodiversity, we focus on examining changes occurring in a particular animal group – birds – as we can access two specific datasets that capture the dynamics of bird species in China. Birds are an important indicator group for biodiversity due to their wide-ranging habitat and sensitivity to the environment.

Our 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 containing 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 2015 to 2021, using reports uploaded to the CBRC. We exclude the city-quarter observations with no birdwatching report, and then empirically explore the effects of GSA on the number of bird species observed through our baseline specification.

The results are reported in Table 8. As shown in Column (1), 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 at least consistent with the notion that local biodiversity benefited from endeavors made by the government on biological conservation through the enforcement of GSA. Furthermore, Columns (2) and (3) show that the intensity of birdwatching activities had no significant change around GSA, evidenced by the number of reports and reporters. This alleviates the plausible concern that the increase in bird species observed could be driven by

more attention from birdwatchers in NNR municipalities compared to that in non-NNR municipalities after GSA.

We also use data from the bird monitoring information system of the Chinese National Ecosystem Research Network (CNERN), an information-sharing platform constructed by the Ministry of Science and Technology, integrating resources of multiple existing field observation and research stations. Specifically, the data on birds are summarized from eleven forest ecological stations that conduct a systematic survey of birds every five years in the corresponding areas.[34] 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 A4 shows that the number of bird species surveyed declined substantially in the first fifteen years of this century, but recovered following GSA. Although it is only suggestive evidence, this pattern is consistent with the poor management of NNRs before GSA and some real positive effects of this reform on biodiversity.

In addition to bird watching data, we attempt to measure the impact of the GSA on local biodiversity using the International Union for Conservation of Nature's Red List of Threatened Species (IUCN Red List) database, a leading source on global species extinction risk. This database includes information on over 163,000 species, with spatial data available for 83% of such species starting from 2017 (IUCN, 2022). We use the IUCN Red List data to construct a measure of number of "potentially observed" species in each location for the years 2017 and 2022. For each Chinese city, we calculate the average number of species across the grid cells within the city's administrative boundaries. Number of species include amphibian, bird, and mammal species. Notice that we only have information on number of species from the IUCN in 2017, which we consider as pre-GSA period, and 2022, which we consider as post-GSA period.

The results are reported in Table A11. We find that NNR municipalities experience a significantly larger increase in the number of potentially observable species between 2017 and 2022, consistent with positive real effects of GSA on local biodiversity. The magnitude of the estimated coefficient in Column (1) indicates a 4.6% larger increase in number of species in NNR municipalities relative to the average number observed in non-NNR municipalities in the baseline year 2017 (260 species). In Column (2) of Table A11 we use as outcome variable the city ranking in number of species within China (where a lower number indicates a higher ranking). As shown, NNR municipalities gain on average 10 positions in the ranking of Chinese cities based on number of species.

[34] The stations are: 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.

6.2 Investors' Learning Through GSA

Our previous discussions focus on mechanisms related to investors' concerns about the transition costs. However, it is possible that some investors' decisions are motivated by non-pecuniary values (Starks, 2023). Suppose that in the MCB market there are a considerable number of investors who really care about biodiversity value for the sake of their non-pecuniary preference. 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 main reactions of these impact investors to GSA may not be any appreciation of the governments' forthcoming efforts, but may be blames on local authorities for past negligence and incurred biodiversity loss. Under this assumption, the existence of a large number (or a few but well-capitalized) impact investors would further increase local public financing costs.

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 does not trigger significant incentives to punish NNR municipalities. As an imperfect proxy for this channel, we collect newspaper coverage of NNRs from *WiseNews*, a leading Chinese newspaper aggregator. We measure the degree of information availability by whether any NNR was covered by the top 10 newspapers (by average circulation) in 2016. As shown in Table A12, NNR municipalities with different levels of information asymmetry associated with their own NNRs saw similar increases in MCB spreads around GSA, compared to non-NNR municipalities. Furthermore, the information effect of GSA ought to gradually weaken over time, which is inconsistent with the pattern presented in Figure 4. In a nutshell, the heightened premium observed around GSA does not seem to be driven by information updating of impact investors that care about biodiversity.

6.3 Investors' Value Versus Values

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 GSA reveals a prevailing market apprehension about the costs incurred by ecological transition, favorable investment strategies that focus on biodiversity improvements as a declared objective could mitigate the increase in the public cost of capital, thereby benefiting social welfare.

To test this channel, we construct a municipality-level proxy of observed biodiversity improvement around the introduction of GSA. We categorize the birdwatching 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, subsequently calculating the corresponding changes from the pre-GSA to the post-GSA period. Then, we compare the effect of GSA on bond spreads in the top quartile of NNR municipalities, which exhibit a substantial increase in bird species observed around GSA, with other NNR municipalities. To enhance robustness, we use changes in the number of species from 2017 to 2022, based on the IUCN Red List data described in Section 6.1, as an alternative measure of biodiversity improvements. The results presented in Table A13 reveal that these NNR municipalities with greater improvements in local biodiversity did not experience a lower rise in MCB spreads. The role of pricing conservation costs behind biodiversity enrichment seems to dominate.

In addition, 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 higher biological value are more likely to be covered by newspapers, then NNR municipalities with more NNR news should 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 discussed in Section 6.2, Table A12 shows very small differences associated with ex-ante media attention on NNRs. 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 does not play a dominant role in the financial market.

These findings suggest the absence of impact investments that favor ecological enhancement in the MCB market. In early 2024, Nobel Laureate Michael Spence emphasized the empowerment of consumers, urging them to discern and support companies that prioritize climate change as a fundamental aspect of their business strategy.[35] Our findings suggest 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 between conceptual understanding and action.

6.4 Aggregate Financing Costs

We propose a back-of-the-envelope calculation of the additional financing costs for LGFVs with outstanding MCBs, as a way to assess the aggregate financing costs of GSA. 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.

[35] The concepts related to societal and environmental well-being implied by the lecture also applies to biodiversity conservation (see more details in: https://etinsights.et-edge.com/ai-looms-india-thrives-nobel-laureate-michael-spence-on-navigating-a-fractured-world/).

As depicted in Figure 7, the debt cost escalated following the GSA implementation: public financing costs (the solid red line) began to rise substantially in 2018 and reached approximately US 120 billion dollars in 2021.

To compute the counterfactual debt servicing costs for Chinese municipalities in the absence of GSA we proceed as follows. First, we estimate a version of Equation (2) in which observations are weighted by the initial level of outstanding debt in each municipality.[36] Weighting municipalities by their debt size allows us to obtain estimates of the effect of NNRs on spreads that are representative of the aggregate Chinese economy rather than of the average municipality in our sample. Next, for each NNR municipality and year, we compute the counterfactual spread they would have faced in the absence of an NNR by subtracting the estimated coefficients in the first step from the observed spread. Finally, we multiply the counterfactual spread by the level of debt of each municipality and sum across all municipalities to obtain the aggregate counterfactual financial cost.

Counterfactual financing costs in the absence of GSA are represented by the dashed blue line reported in Figure 7. The gap between actual and counterfactual financing costs has been increasing year by year since the introduction of GSA. In total, the additional LGFV interest payments incurred by GSA from 2018 to 2021 amounted to approximately 40 billion dollars.

Recent estimates by Deutz *et al.* (2020) indicate that the gap between the funding needs and the actual funding available to preserve biodiversity at the global level (or biodiversity financing gap) is approximately 711 billion dollars per year. If countries were to share such biodiversity spending in proportion to their share of global species, China would need to spend 45.5 billion dollars per year on protecting biodiversity (see Table A15). However, these estimates do not take into account the extra financing costs associated with biodiversity conservation, which in the case of GSA in China account for 11.33%, 17.95%, and 29.57% of the total costs (45.5 billion dollars) in 2019, 2020, and 2021, respectively.[37] This suggests that, in practice, the cost of protecting biodiversity is higher than what is implied by simply considering the direct investment in conservation. Empirical evidence from GSA indicates that indirect costs related to changes in the cost of capital can be of significant magnitude, and scholars and policymakers should not overlook them in designing global biodiversity conservation frameworks.

[36] Specifically, the weighting factor in practice is the city-level average value of LGFV interesting-bearing debts from 2013 to 2016. We also conduct a robustness test using the weighted least square (WLS) approach to estimate Equation (1) and still observe a statistically significant increasing effect of GSA on MCB spreads (see Table A14).

[37] We also calculated the biodiversity financing gap allocated to China based on its share of global land area (GDP). We found that the additional interest payments brought by GSA as a percentage of the biodiversity investment demand for the respective years 2019-2021 were 0.55% (3.99%), 23.19% (8.77%), and 43.08% (16.30%).

7 Conclusion

We study the relationship between biodiversity conservation and its cost imposed on the public financing of governments. In particular, we exploit the Green Shield Action (GSA) in China as a shock to local financial and fiscal burdens and study market responses in the municipal corporate bond (MCB) markets. Evidence indicates that cities with National Nature Reserves (NNRs) experienced greater increases in the general 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 the level of financing demand of local governments, heightened political risk, or related information disclosure. We also find that, although the GSA improved biodiversity, MCB investors are not considering these ecological values when making investment decisions, nor are they financially punishing cities revealed with more environmental degradation. Finally, we provide a conservative estimate of the additional public financing costs GSA has incurred. Given China's abundant natural capital, economic scale, and representative biodiversity, as well as the global nature of biodiversity challenges, our findings provide valuable initial benchmarks for future research and practice.

Our work likely has several policy implications applicable in general settings. First, estimating the financing gap for biodiversity conservation requires considerations beyond direct investments for biodiversity transition. It 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 policies for sustainable development. 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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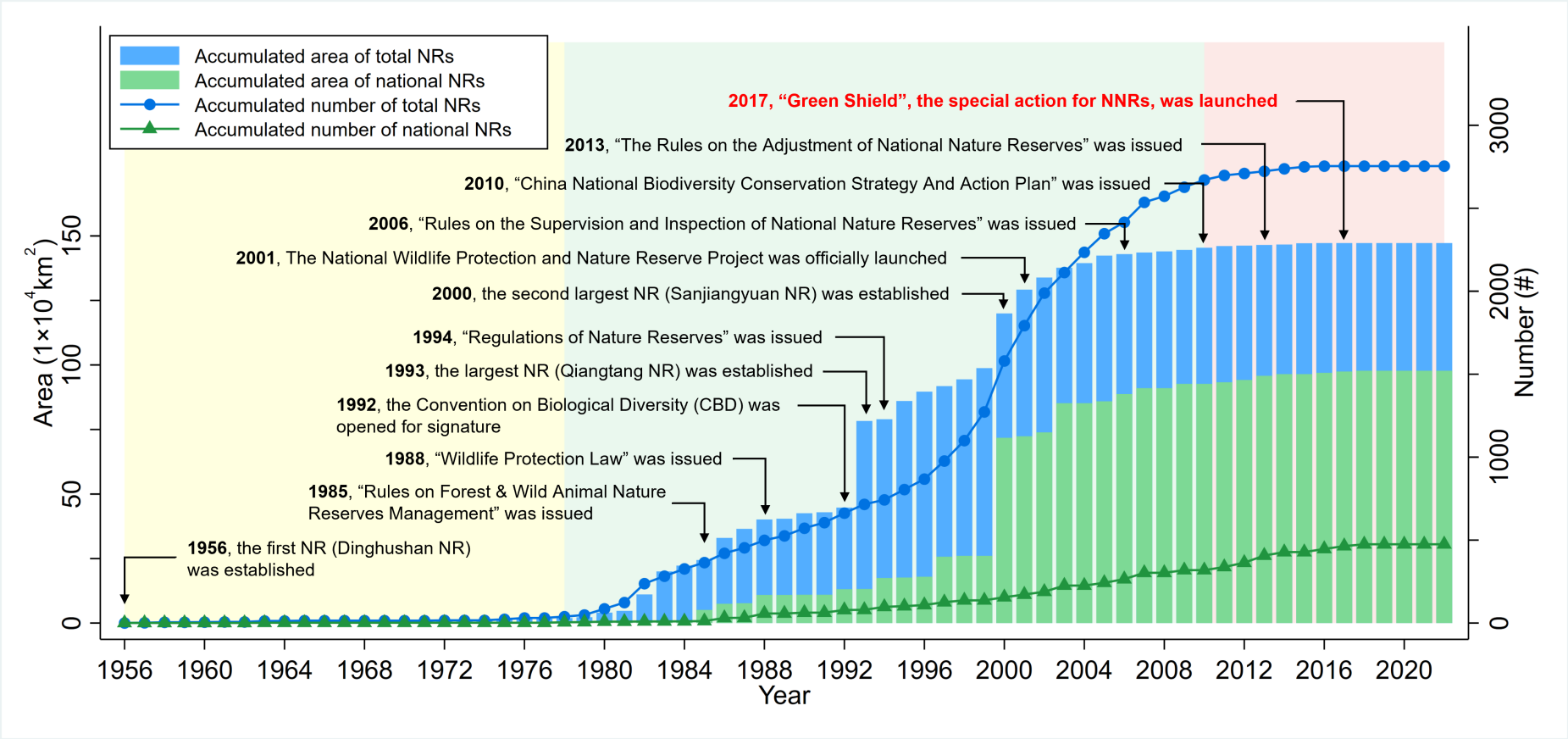
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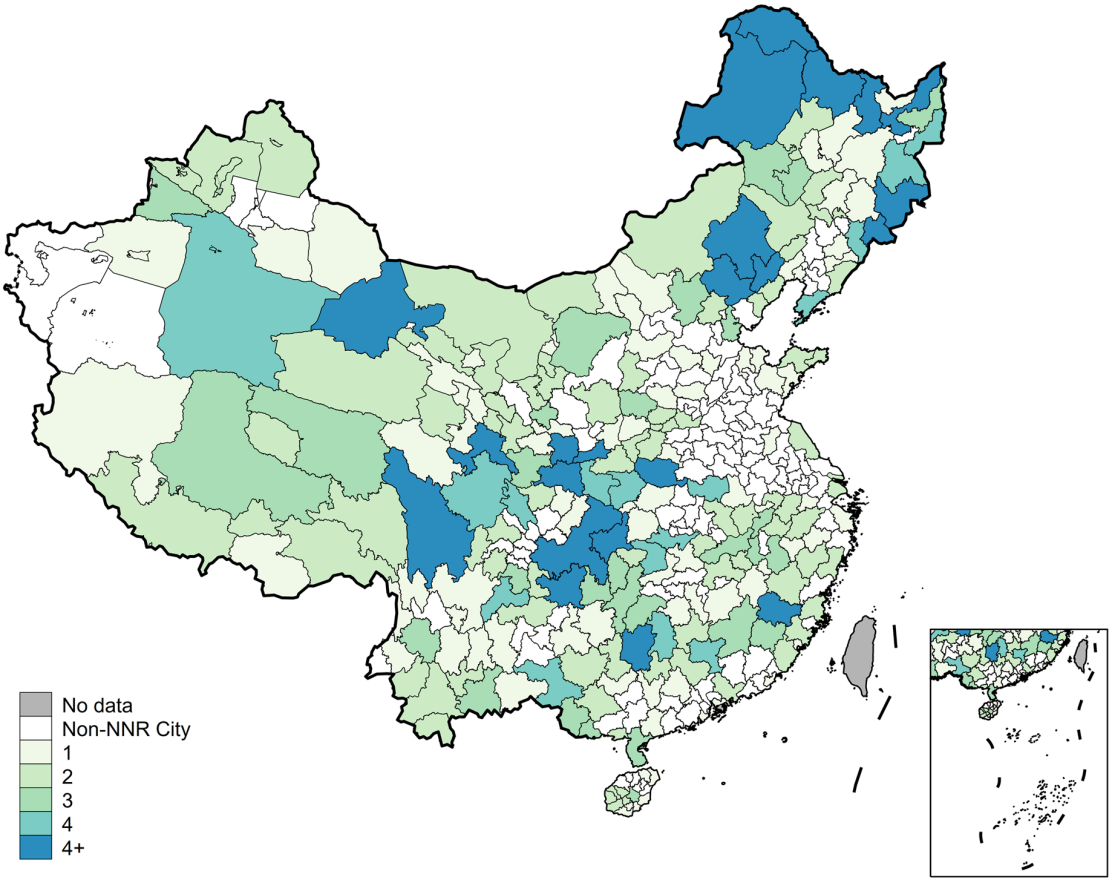
Figures and Tables

Figure 1: Development of Nature Reserves and Important Relevant Events in China



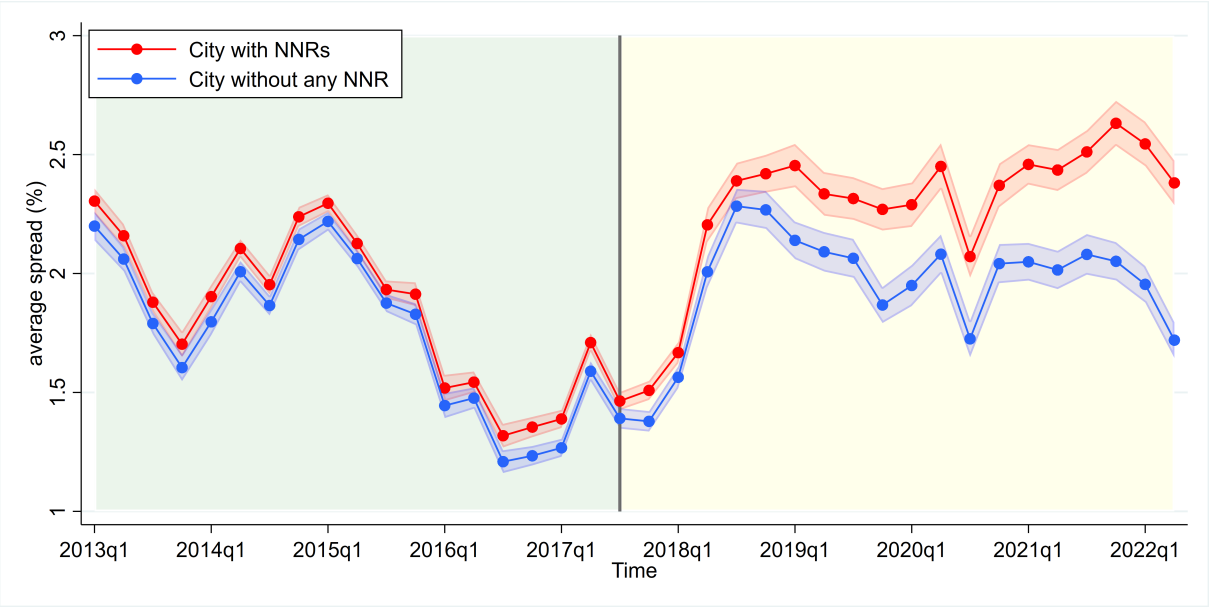
Notes: This figure illustrates the number (right axis) and area (left axis) of national nature reserves (NNRs) in China from 1956 to 2022. Important policies are also marked with arrows in the corresponding year.

Figure 2: The Geographical Distribution of NNRs at the City Level



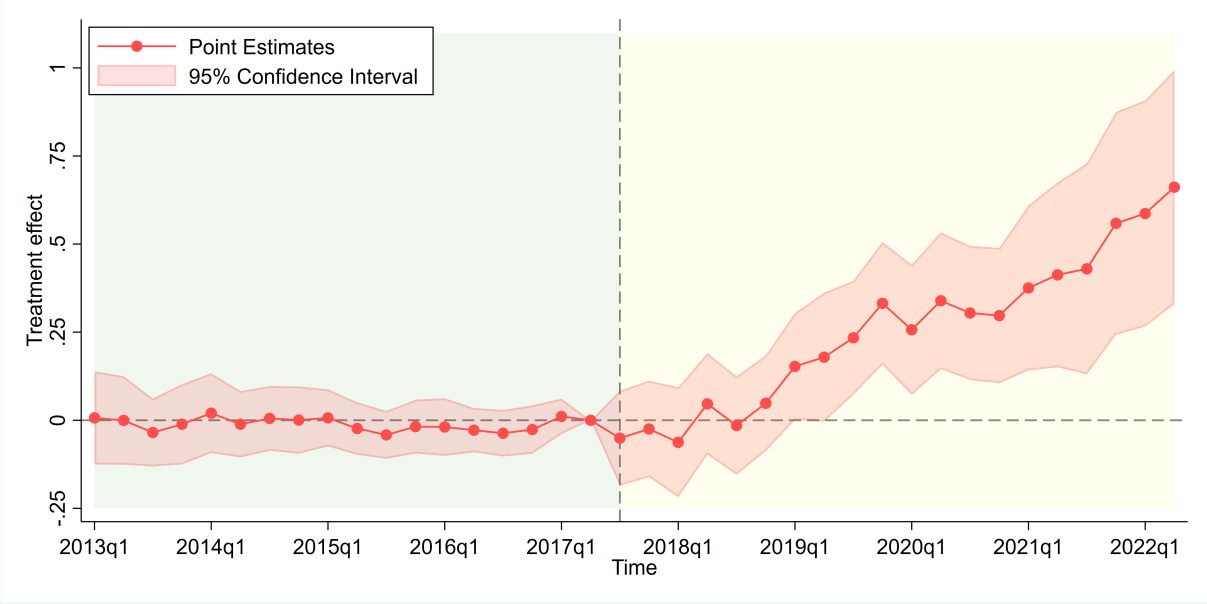
Notes: This figure illustrates the number of national nature reserves (NNRs) in each city in China as of 2016. The regional boundaries are delineated down to the city level. The legend depicts the range of the number of NNRs corresponding to each color depth.

Figure 3: The Dynamics of MCB Spreads over Time



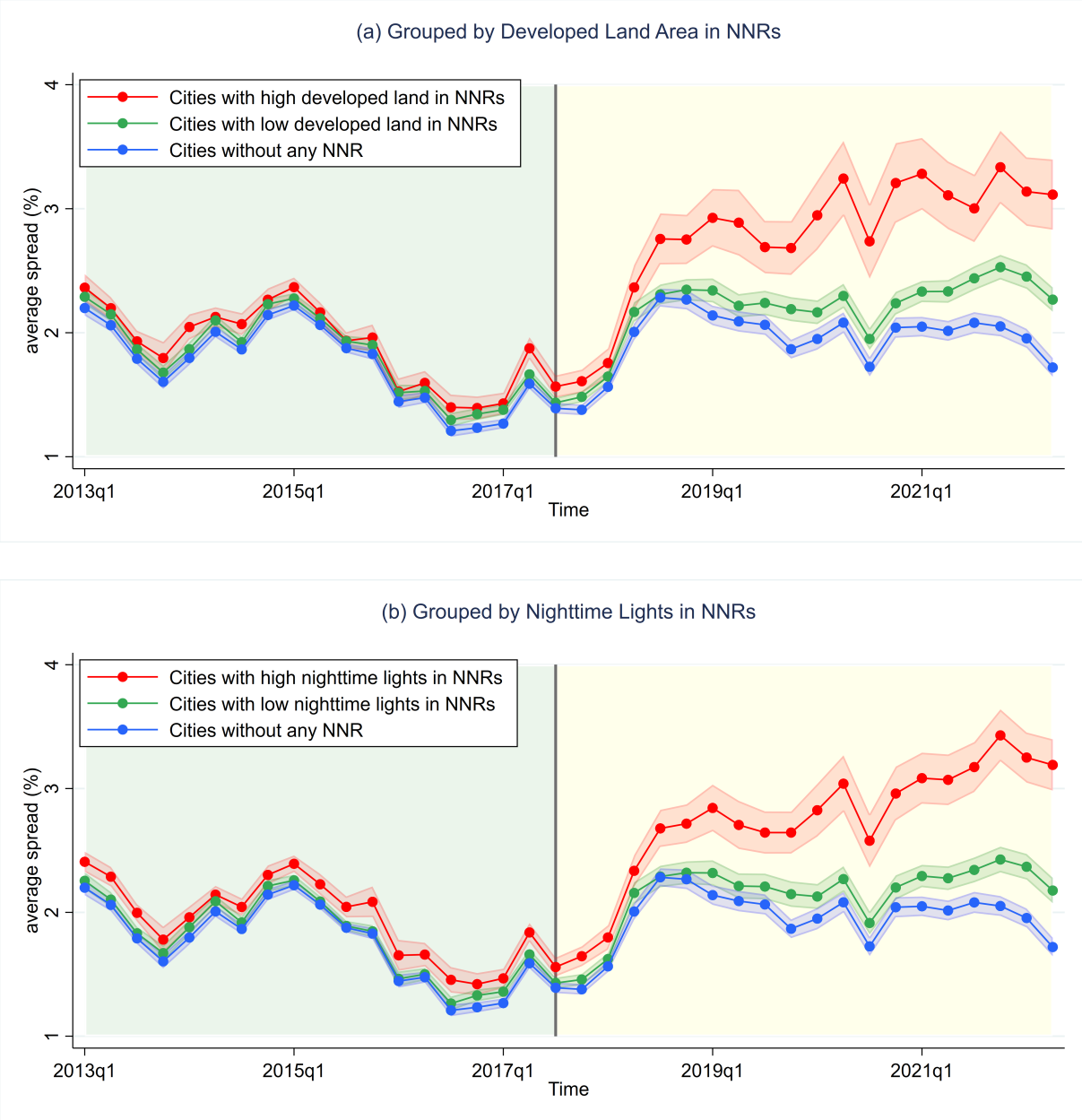
Notes: This figure depicts the raw pattern of average MCB spreads and 95% confidence interval for NNR municipalities and non-NNR municipalities. MCB spread is calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. The solid vertical line represents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

FIGURE 4: CHANGES IN MCB SPREADS BEFORE AND AFTER GSA



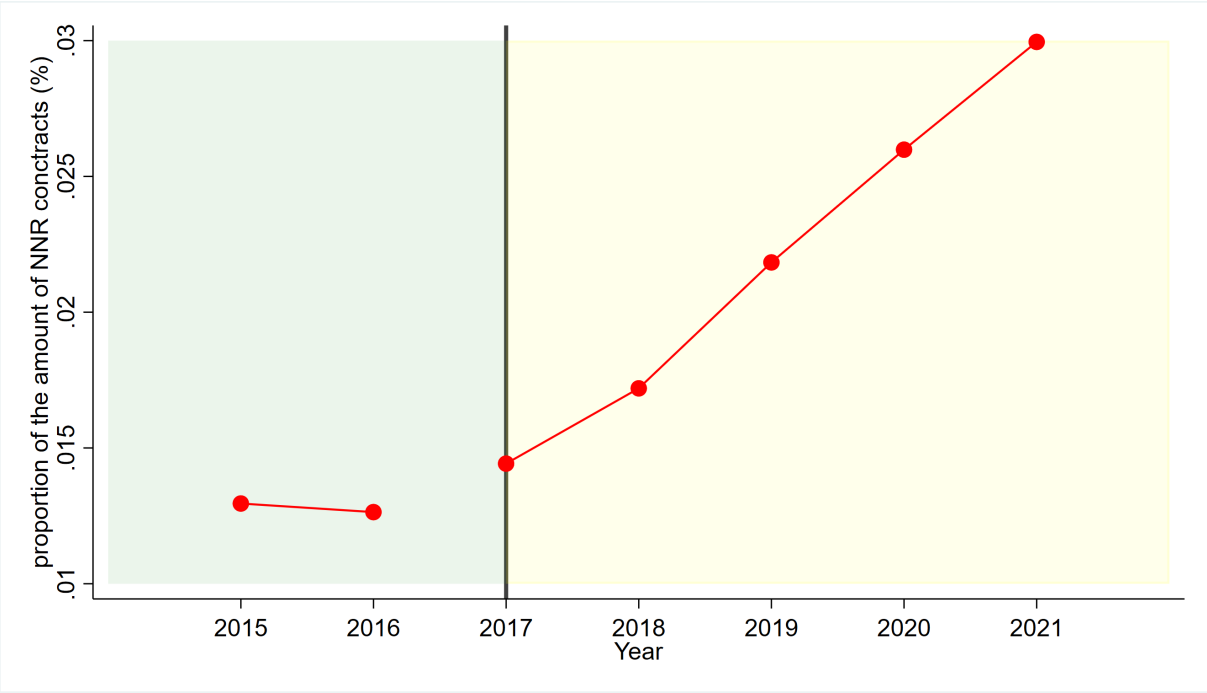
Notes: This figure depicts the estimated differences in MCB spreads between NNR municipalities and non-NNR municipalities before and after GSA. The markers and capped spikes represent the OLS estimators and 95% confidence intervals. The dependent variable is the MCB spread, calculated as the difference 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: PRE-EXISTING ECONOMIC ACTIVITIES WITHIN NNRS



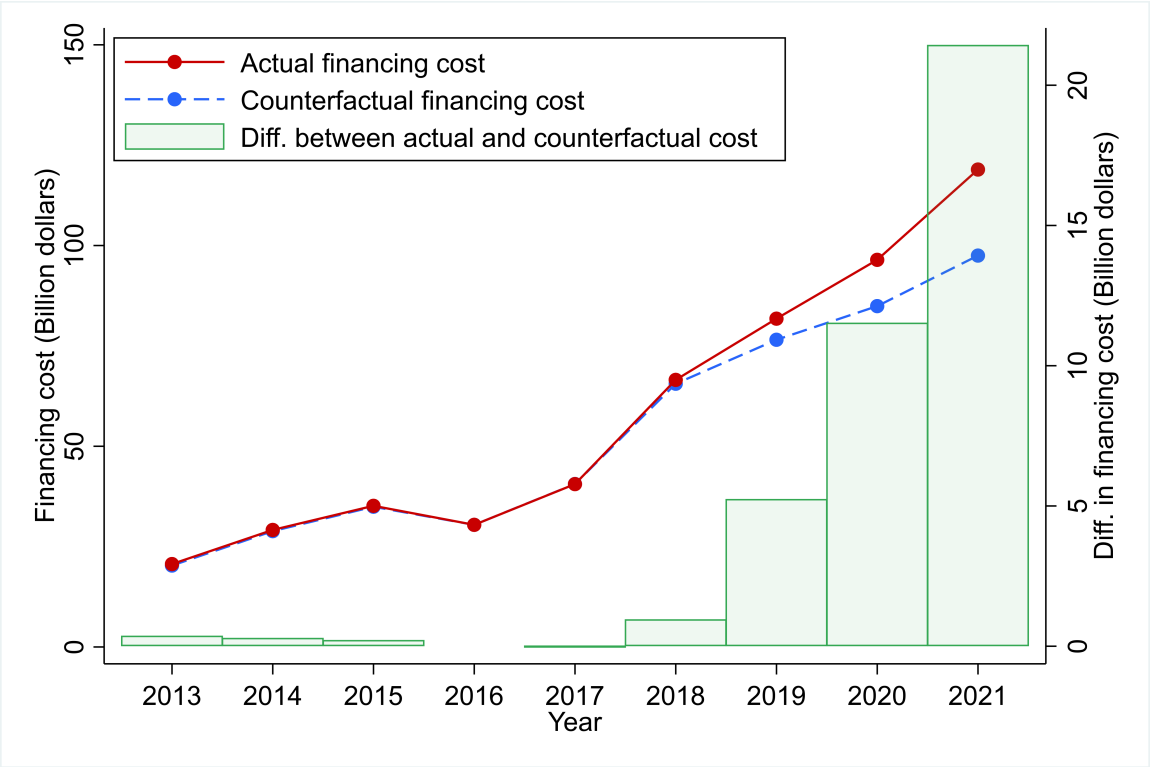
Notes: Panel A of this figure depicts the average MCB spreads and 95% confidence interval for cities in three groups: NNR municipalities in the top quartile of the distribution of developed land area within NNRs in 2016, NNR municipalities not in the top quartile of the distribution of developed land area within NNRs in 2016, and non-NNR municipalities. Panel B of 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. For both panels, 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 the pecuniary value of public procurement on national nature reserves to that of total public procurement from 2015 to 2021. The red dots represent the proportion, the solid red line represents the trend, and the solid vertical 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 cost of LGFVs' debt service over time with and without GSA. The solid red line represents the actual aggregate cost of LGFVs' debt service (the left axis). The blue dashed line represents the counterfactual aggregate cost of LGFVs' debt service (the left axis). The green bar represents the difference between the actual and counterfactual cost (the right axis) over time. The exchange rate between the US dollar and the Chinese RMB yuan is set as 1: 7.

Table 1: Summary Statistics

	Obs	Mean	St.D	P25	P50	P75
Outcome:						
Spread	87885	1.973	1.360	1.014	1.664	2.509
Treatments:						
NNR	87885	0.511	0.500	0.000	1.000	1.000
Post	87885	0.626	0.484	0.000	1.000	1.000
Bond characteristics:						
ln(Bond size)	87885	2.225	0.530	1.946	2.303	2.565
Time to maturity	87885	3.834	1.757	2.364	3.680	5.148
Option	87885	0.692	0.462	0.000	1.000	1.000
Guarantee	87885	0.230	0.421	0.000	0.000	0.000
Exchange	87885	0.323	0.468	0.000	0.000	1.000
Bond rating	87885	2.290	0.822	2.000	2.000	3.000
Issuer rating	87885	2.654	0.732	2.000	3.000	3.000
City pre-shock features:						
ln(GDP)	87885	3.433	0.952	2.669	3.476	4.234
ln(GDP per capita)	87885	3.981	0.512	3.707	4.051	4.412
GDP annual growth rate	87885	10.481	1.670	9.400	10.600	11.771
Tertiary sector in GDP	87885	42.915	9.117	36.489	41.979	47.800
ln(Population)	87885	1.741	0.685	1.354	1.718	2.163
Population annual growth rate	87885	0.710	1.134	0.114	0.416	1.029
ln(Nighttime lights)	87885	2.488	0.755	1.928	2.623	3.038
ln(Fixed investments)	87885	3.061	0.819	2.497	3.008	3.753
ln(Housing price)	87885	1.784	0.447	1.440	1.717	2.043

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. Bond controls contain (ln)bond issuing amount, bond maturity, bond rating, issuer rating, and whether the bond is option-embedded, guaranteed, and traded on exchange. City pre-shock variables include (ln)GDP, (ln)GDP per capita, GDP growth rate, the proportion of tertiary sector in GDP, (ln)population, population growth rate, (ln)nighttime light intensity, (ln)fixed investment, and (ln)housing price at the city level in 2013. City-level continuous variables are winsorized at the 0.5th and 99.5th percentiles. Detailed variable definitions are presented in Table A1.

Table 2: Pre-GSA Levels and Trends in Municipality Characteristics

	NNR=1	NNR=0	Difference
	(1)	(2)	(1)-(2)
ln GDP (ten billion RMB)	2.531	2.669	-0.138
	(0.067)	(0.089)	[0.110]
Δ ln GDP (ten billion RMB)	0.160	0.176	-0.015
	(0.014)	(0.017)	[0.022]
ln GDP per capita (thousand RMB)	3.650	3.682	-0.031
	(0.042)	(0.053)	[0.067]
Δ ln GDP per capita (thousand RMB)	0.140	0.157	-0.017
	(0.014)	(0.016)	[0.021]
GDP annual growth rate (%)	10.228	10.777	-0.549**
	(0.171)	(0.201)	[0.268]
Δ GDP annual growth rate (%)	-3.198	-3.485	0.287
	(0.266)	(0.311)	[0.416]
Tertiary sector GDP (%)	37.727	38.368	-0.642
	(0.734)	(0.813)	[1.126]
Δ Tertiary sector GDP (%)	6.401	6.356	0.045
	(0.375)	(0.446)	[0.590]
ln Nighttime light intensity	1.973	2.043	-0.070
	(0.054)	(0.072)	[0.089]
Δ ln Nighttime light intensity	0.089	0.065	0.023***
	(0.005)	(0.005)	[0.007]
ln Housing price (thousand RMB/ m^2)	1.489	1.528	-0.039
	(0.030)	(0.033)	[0.046]
Δ ln Housing price (thousand RMB/ m^2)	0.091	0.091	-0.001
	(0.012)	(0.013)	[0.018]
ln Fixed investment (ten billion RMB)	2.296	2.371	-0.076
	(0.059)	(0.078)	[0.097]
Δ ln Fixed investment (ten billion RMB)	0.252	0.269	-0.017
	(0.034)	(0.041)	[0.054]
ln Population (million)	1.177	1.280	-0.103
	(0.057)	(0.069)	[0.090]
Δ ln Population (million)	0.007	0.020	-0.013*
	(0.004)	(0.005)	[0.007]
Population annual growth rate (%)	0.266	0.498	-0.233
	(0.104)	(0.117)	[0.160]
Δ Population annual growth rate (%)	-0.048	0.113	-0.161
	(0.156)	(0.209)	[0.257]
Urbanization rate (%)	30.181	29.060	1.121
	(1.101)	(1.399)	[1.775]
High school and above education rate (%)	21.815	21.787	0.029
	(0.573)	(0.831)	[0.978]
ln Local fiscal revenue (million RMB)	2.306	2.413	-0.107
	(0.076)	(0.095)	[0.122]
Δ ln Local fiscal revenue (million RMB)	0.162	0.179	-0.017
	(0.018)	(0.023)	[0.030]
ln Local fiscal expenditure (million RMB)	3.207	3.140	0.067
	(0.052)	(0.062)	[0.081]
Δ ln Local fiscal expenditure (million RMB)	0.281	0.293	-0.011
	(0.012)	(0.015)	[0.019]

Notes: This table presents pre-GSA economic characteristics for NNR and non-NNR municipalities (Columns (1) and (2), respectively) and their differences (Column (3)). Urbanization and high school education rates are from the 2010 census (no suitable observations are available to calculate pre-GSA trends due to the decennial nature of the population census in China). The other variables in levels are each measured as of 2013 (the start of our sample period), and their trends (marked with Δ) compare the data from 2016 (the year just before the GSA launch) to that of 2013. Standard deviations are in parentheses and standard errors are in brackets. Detailed variable definitions are presented in Table A1. Cities are restricted to those in baseline sample (consistent with Table 1 and Table 3). The exchange rate between the US dollar and the Chinese RMB was typically between 1:6 and 1:7.

Table 3: GSA and MCB Spreads: Baseline Estimates

	Spread			
	(1)	(2)	(3)	(4)
NNR × Post	0.270***	0.250***	0.256***	0.237***
	(0.101)	(0.094)	(0.075)	(0.072)
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Bond controls	No	Yes	No	Yes
City pre-shock var. × Post	No	No	Yes	Yes
Adjusted R^2	0.493	0.552	0.503	0.561
Obs	87885	87885	87885	87885

Notes: This table reports the regression results of the impact of GSA on MCB spreads based on the specification of Equation (1). 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. Regressions include year-quarter and issuer fixed effects. Bond controls contain (ln)bond issuing amount, bond maturity, bond rating, issuer rating, and whether the bond is option-embedded, guaranteed, and traded on exchange. City pre-shock variables include (ln)GDP, (ln)GDP per capita, GDP growth rate, the proportion of tertiary sector in GDP, (ln)population, population growth rate, (ln)nighttime light intensity, (ln)fixed investment, and (ln)housing price at city level in 2013. Detailed definitions of control variables are presented in Table A1. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 4: GSA and MCB Spreads: Placebo Test

	Spread			
	(1)	(2)	(3)	(4)
NNR × Post	0.237***	0.234***	0.233***	0.229***
	(0.072)	(0.073)	(0.074)	(0.076)
ProvNR × Post	-0.048			-0.049
	(0.093)			(0.093)
CityNR × Post		-0.014		-0.017
		(0.076)		(0.080)
CountyNR × Post			0.026	0.032
			(0.077)	(0.081)
Controls	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.561	0.561	0.561	0.561
Obs	87885	87885	87885	87885

Notes: This table reports the impact of owning different types of nature reserves on MCB spreads around GSA. 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. *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. Regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. 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

Grouping reference	Spread			
	Developed land area		Nighttime light intensity	
	(1)	(2)	(3)	(4)
NNR × Post × High ex-ante economic activity in NNRs	0.495***	0.307**	0.353**	0.210*
	(0.128)	(0.133)	(0.138)	(0.122)
NNR × Post	0.183*	0.176**	0.181	0.184**
	(0.105)	(0.075)	(0.110)	(0.077)
Other terms of triple differences	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.495	0.562	0.494	0.562
Obs	87885	87885	87885	87885

Notes: This table reports the estimated heterogeneous effects of GSA on MCB spreads in pre-existing human economic activities within NNRs. 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. *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. The intensity of human economic activities is measured by the developed land area within NNRs in Column (1)-(2) and nighttime light intensity within NNRs in Column (3)-(4), respectively. Regressions include all required components of the triple-difference model, year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses are clustered at the city level. ***, **, 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

	Fiscal deficit	
	(1)	(2)
NNR × Post	0.253***	0.203**
	(0.097)	(0.079)
Controls	No	Yes
Year FE	Yes	Yes
City FE	Yes	Yes
Adjusted R^2	0.924	0.932
Obs	2725	2725

Panel B: GSA and MCB spreads: local debt pressure

	Spread	
Grouping reference	Total debt	Interest-bearing debt
	(1)	(2)
NNR × Post × High debt burden	0.245*	0.286**
	(0.127)	(0.136)
NNR × Post	0.120	0.097
	(0.093)	(0.098)
Other terms of triple differences	Yes	Yes
Controls	Yes	Yes
Year-quarter FE	Yes	Yes
Issuer FE	Yes	Yes
Adjusted R^2	0.562	0.563
Obs	87837	87837

Notes: This table reports the role of local public 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 in both panels. Panel A reports the effects of GSA on local fiscal conditions at the city-year level. The dependent variable in Panel A, *Fiscal deficit*, is the ratio of the difference between annual fiscal expenditures and revenues, to fiscal revenues. *Post* in Panel A is a dummy variable that equals one in and after 2017 and zero otherwise. Regressions in Panel A include year and city fixed effects, as well as the city-level control variables (i.e., *city pre-shock var.*×*Post* used in Table 3). Panel B reports the heterogeneous effects of GSA on MCB spreads in local public debt burden. The dependent variable in Panel B is MCB spread. *Post* in Panel B is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. *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 city GDP, respectively. Regressions in Panel B include all required components of the triple-difference model, year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses of both panels 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

	Spread					
Grouping reference	Long Term >3 years			Long Term >4 years		
Sample	Short Term	Long Term	Full Sample	Short Term	Long Term	Full Sample
	(1)	(2)	(3)	(4)	(5)	(6)
NNR × Post	0.342***	0.178***	0.311***	0.307***	0.151**	0.278***
	(0.097)	(0.066)	(0.091)	(0.076)	(0.077)	(0.078)
NNR × Post × **1**[Long Term]			-0.164**			-0.153**
			(0.075)			(0.072)
Other terms of triple differences			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
Adjusted R^2	0.587	0.655	0.563	0.580	0.673	0.562
Obs	35260	52625	87885	48414	39471	87885

Notes: This table reports the estimated 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. Column (3) and (6) include all required components of the triple-difference model. All regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table 8: GSA and Bird-watching Activities

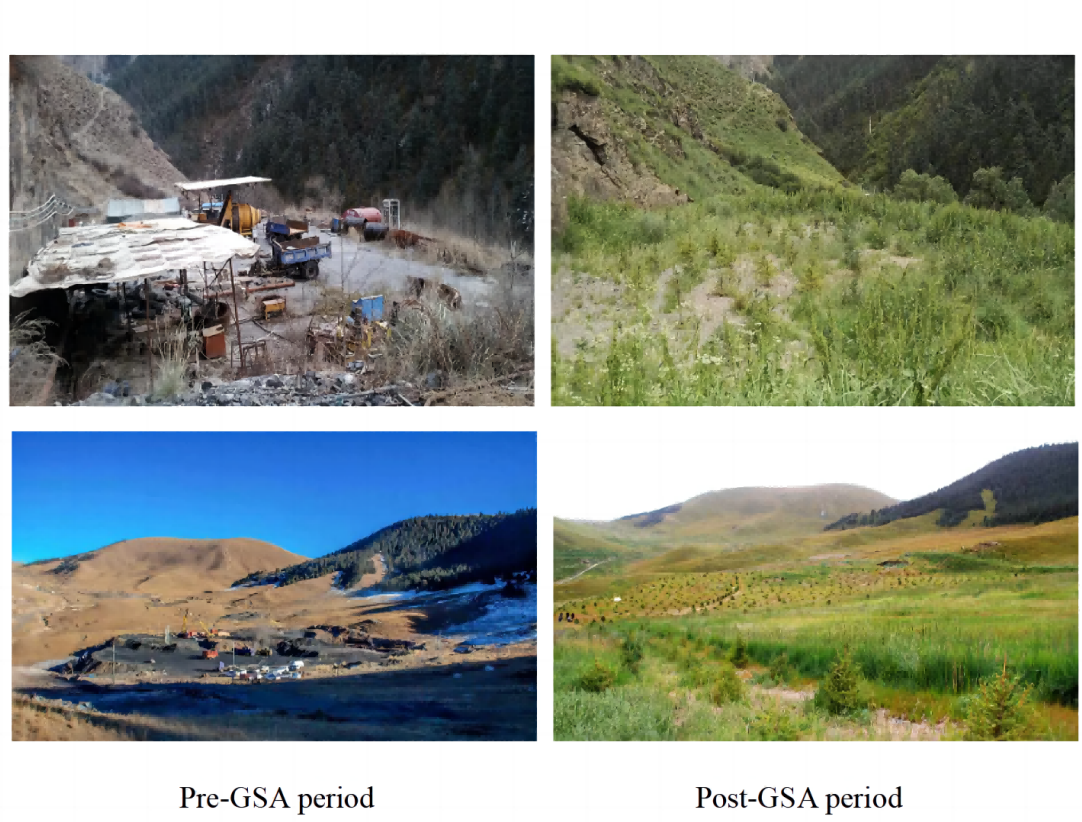
Dependent	# of bird species observed	# of birdwatching reporters	# of birdwatching reports
	(1)	(2)	(3)
NNR × Post	9.240**	0.646	1.370
	(4.625)	(1.040)	(6.240)
Year-quarter FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Adjusted R^2	0.606	0.538	0.456
Obs	4582	4582	4582

Notes: This table reports the city-quarter-level regression results of the effects of GSA on the birdwatching activities reported on the China Bird Report Center. The dependent variables in Columns (1)-(3) are the number of bird species observed, the number of birdwatching reporters and the number of birdwatching reports, 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. Regressions include year-quarter and city fixed effects. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Internet Appendix

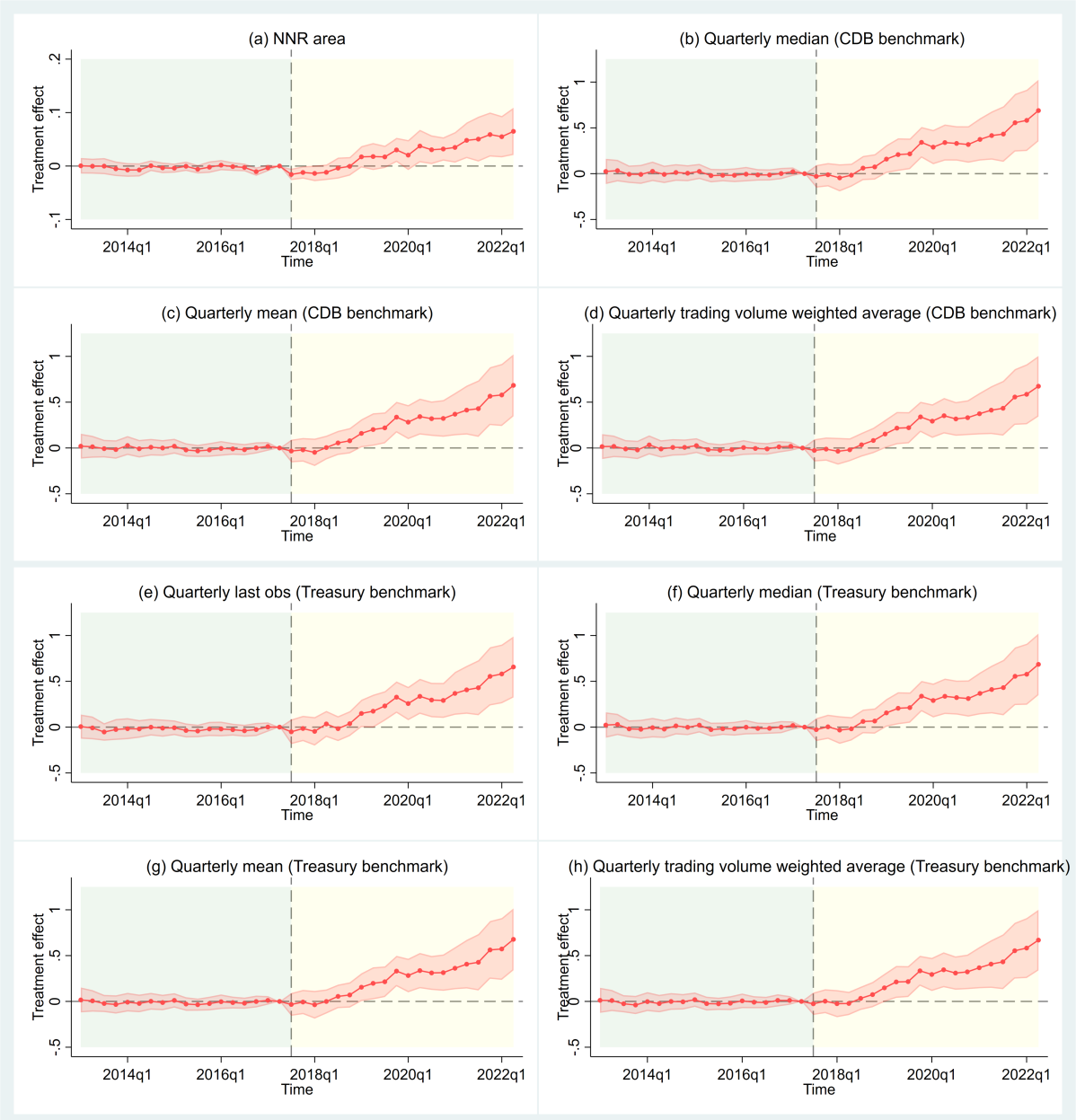
A Additional Tables and Figures

Figure A1: Changes in the Biological Condition of the Qilian Mountain National Nature Reserve around GSA



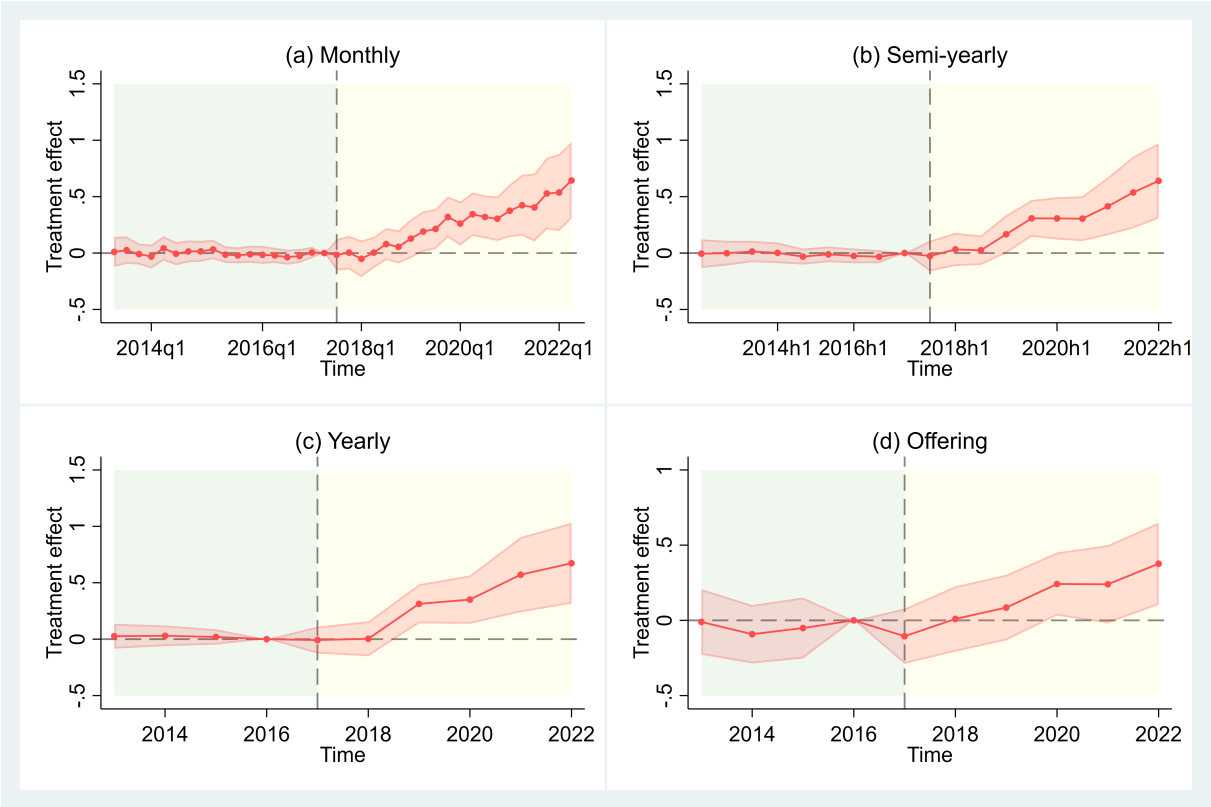
Notes: This figure illustrates the contrast in the biological condition within the Qilian Mountain National Nature Reserve before and after GSA, from the perspectives of the disposal of illegal hydropower facilities (the upper part) and colliery (the bottom part). See more details in: https://www.mee.gov.cn/ywgz/zysthjbhdc/dczg/202102/t20210206_820575.shtml.

Figure A2: Changes in MCB Spreads Before and After GSA: Alternative Measures



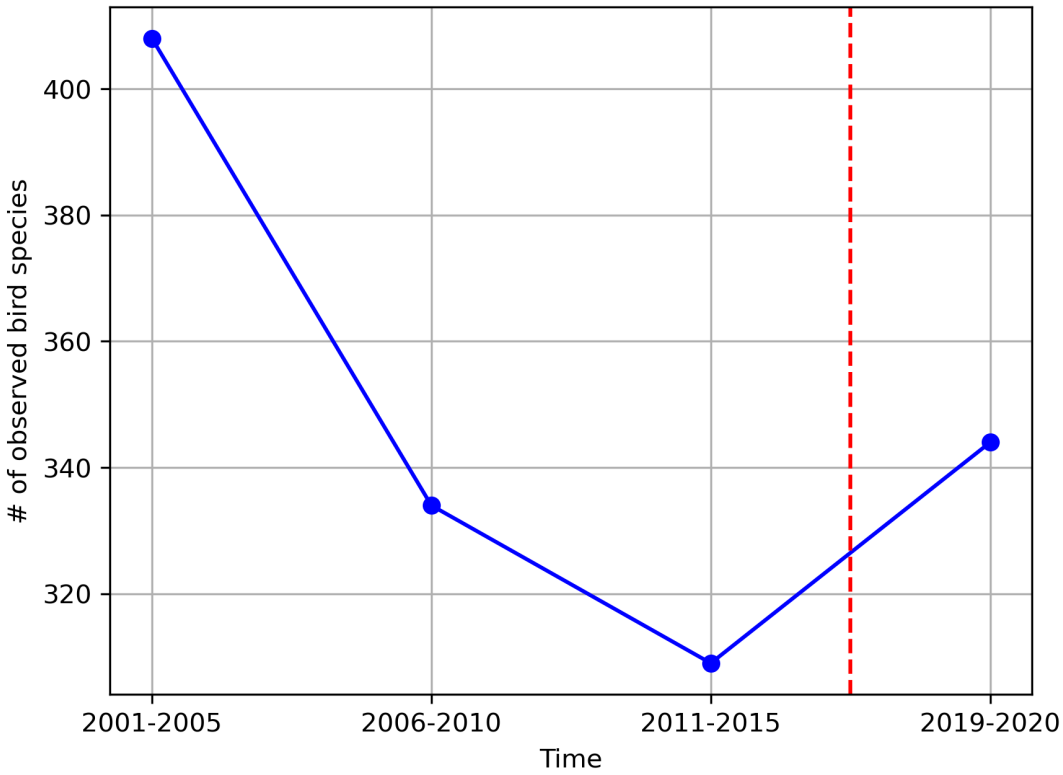
Notes: This figure depicts results of robustness tests on estimated differences in MCB spreads between NNR municipalities and non-NNR municipalities, by replacing the measures of main variables in Figure 4. Panel A presents the result using an alternative measure of treatment intensity: the proportion of NNRs in the area of urban administrative areas within a city. Panel B-H present the results using alternative measures of spreads: Panel B-D employ the quarterly median, the quarterly mean, and the quarterly trading-volume-weighted average of MCB spreads, respectively, using the risk-free benchmark of CDB yield; Panel E-H replace the risk-free benchmark with the Treasury yield.

FIGURE A3: GSA AND MCB SPREADS: 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 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 Panel D.

Figure A4: 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.

Table A1: Definitions of Variables

Variable	Definition
Bond size	The 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.
Guarantee	A dummy variable that equals one if a bond is guaranteed 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.
GDP	The gross domestic product of the corresponding city in 2013, in ten billion yuan RMB.
GDP per capita	The GDP per capita of the corresponding city in 2013, in thousand yuan RMB.
GDP annual growth rate	The ratio of the difference between GDP in 2013 and that in 2012 to the GDP in 2012 of the corresponding city, in percentage.
Tertiary sector GDP	The ratio of the tertiary sector in GDP of the corresponding city in 2013, in percentage.
Nighttime lights	The nighttime light intensity of the corresponding city in 2013.
Fixed investments	The fixed investments of the corresponding city in 2013, in ten billion RMB yuan.
Housing price	The average selling price of commercial housing of the corresponding city in 2013, in thousand RMB yuan per square meter.
Population	The permanent resident population of the corresponding city in 2013, in million people.
Population annual growth rate	The ratio of the difference between permanent resident population in 2013 and that in 2012 to the permanent resident population in 2012 of the corresponding city, in percentage.
Urbanization rate	The ratio of non-agricultural residents to the total population of the corresponding city in 2010, in percentage.
High school and above education rate	The ratio of population with high school education or above to the total population of the corresponding city in 2010, in percentage.
Local fiscal revenue	The general budget revenue of the corresponding city government in 2013, in million yuan RMB.
Local fiscal expenditure	The general budget expenditure of the corresponding city government in 2013, in million yuan RMB.

Notes: This table reports the detailed definitions of baseline controls (see Table 3) and balance-test variables (see Table 2). Bond-level variables are collected from WIND. The intensity of nighttime lights at the city level are calculated based on the raster data of Zhang *et al.* (2021). Urbanization and high school education rates are collected from the 2010 census (In China, censuses are conducted every ten years and many city governments do not release detailed demographic data annually). Other city-level variables are collected by the National Bureau of Statistics and local statistical yearbooks in China. The exchange rate between the US dollar and the Chinese RMB yuan was typically between 1:6 and 1:7.

Table A2: GSA and MCB Spreads: Alternative Measures of Treatment Intensity

	Spread			
	(1)	(2)	(3)	(4)
NNR area × Post	0.039***	0.035***	0.022**	0.020**
	(0.008)	(0.008)	(0.009)	(0.008)
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Bond controls	No	Yes	No	Yes
City pre-shock var. × Post	No	No	Yes	Yes
Adjusted R^2	0.493	0.552	0.502	0.561
Obs	87885	87885	87885	87885

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. *NNR area* is a continuous variable that represents the proportion of the area of NNR within the city where the issuer is located. *Post* is a dummy variable that equals one after the second quarter of 2017 and zero otherwise. Regressions include year-quarter and issuer fixed effects. Bond controls contain (ln)bond issuing amount, bond maturity, bond rating, issuer rating, and whether the bond is option-embedded, guaranteed and traded on exchange. City pre-shock variables include (ln)GDP, (ln)GDP per capita, GDP growth rate, the proportion of tertiary sector in GDP, (ln)population, population growth rate, (ln)nighttime light intensity, (ln)fixed investment, and (ln)housing price at the city level in 2013. Detailed variable definitions are presented in Table A1. 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 SPREADS

	Benchmark: CDB yield			Benchmark: Treasury yield			
	Quarterly median	Quarterly mean	Quarterly trading volume weighted average	Quarterly last obs	Quarterly median	Quarterly mean	Quarterly trading volume weighted average
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
NNR × Post	0.235***	0.237***	0.234***	0.241***	0.238***	0.241***	0.238***
	(0.071)	(0.072)	(0.070)	(0.071)	(0.071)	(0.071)	(0.070)
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
Adjusted R^2	0.583	0.586	0.585	0.559	0.580	0.583	0.581
Obs	87885	87885	87259	87885	87885	87885	87259

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 the quarterly median of spreads, the quarterly mean of spreads, the quarterly trading-volume-weighted weighted spreads in Columns (1)-(3), respectively, using the risk-free benchmark of CDB yield. Columns (4)-(7) replace the benchmark with Treasury yield. *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. Regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. 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 Frequencies of Bond Sample

Freq.	Spread			
	Monthly	Semi-yearly	Yearly	Offering
	(1)	(2)	(3)	(4)
NNR×Post	0.243***	0.250***	0.235***	0.187**
	(0.077)	(0.074)	(0.075)	(0.080)
Controls	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Observations	166265	52767	32119	8961
Adjusted R^2	0.580	0.545	0.550	0.829

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 constructed by choosing the last observation of monthly frequency, semi-yearly frequency, and yearly frequency for each bond in Columns (1)-(3), respectively. The estimation results with the bond offering sample are also reported in Column (4). 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. Regressions include time (corresponding frequency, with quarter fixed effects for the offering sample) and issuer fixed effects, as well as all controls defined in Table 3. 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 Samples

	Spread			
	(1)	(2)	(3)	(4)
NNR × Post	0.227***	0.253***	0.284***	0.264***
	(0.076)	(0.072)	(0.079)	(0.083)
Controls	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.563	0.564	0.562	0.564
Obs	80967	84623	76890	69424

Notes: This table reports the regression results of the impact of GSA on MCB spreads using alternative samples of NNR and non-NNR municipalities. Column (1) excludes NNR municipalities in the top quartile of the distribution of *NNR area* described in Section 4.2 in 2016. Column (2) uses only non-NNR municipalities adjacent to an NNR municipality as control group. Column (3) uses only non-NNR municipalities within a 50 km radius from an NNR municipality. Column (4) uses the intersection set of samples from Columns (1)-(3). The dependent variable is the MCB spread, calculated as the difference between the MCB yield and the CDB yield on the same day and of the same maturity. The variable *NNR* is a dummy 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. Regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Detailed variable definitions are presented in Table A1. Standard errors clustered at the city level are shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table A6: GSA and MCB Spreads: Central Inspection on Environmental Protection

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
NNR × Post	0.237***	0.237***	0.236***	0.233***	0.229***	0.226***
	(0.072)	(0.072)	(0.072)	(0.072)	(0.072)	(0.073)
In the 1st round	0.055**		0.055**			
	(0.025)		(0.025)			
In the 2nd round		-0.017	-0.017			
		(0.049)	(0.049)			
After the 1st round				0.086**		0.082**
				(0.038)		(0.037)
After the 2nd round					0.084	0.082
					(0.066)	(0.066)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.561	0.561	0.561	0.561	0.561	0.561
Obs	87885	87885	87885	87885	87885	87885

Notes: This table reports the effects of the Central Inspection on Environmental Protection (CIEP) on MCB spreads. 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. *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 for provinces investigated in the first (second) round after the first quarter of investigation and zero otherwise. All regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses are clustered at city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A7: GSA and MCB Spreads: Nationwide Battle to Prevent and Control Pollution

	Spread					
	(1)	(2)	(3)	(4)	(5)	(6)
NNR × Post	0.200***	0.229***	0.220***	0.218***	0.213***	0.186**
	(0.076)	(0.073)	(0.074)	(0.075)	(0.076)	(0.080)
AQI × Post2018Q1	-0.004					-0.004
	(0.003)					(0.003)
Industrial SO2 / GDP2 × Post2018Q1		0.718***			0.698***	0.681***
		(0.115)			(0.158)	(0.154)
industrial sewage / GDP2 × Post2018Q1			-0.049		-0.315*	-0.333**
			(0.171)		(0.167)	(0.166)
Industrial dust / GDP2 × Post2018Q1				0.697***	0.281	0.302
				(0.240)	(0.280)	(0.274)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.553	0.549	0.546	0.546	0.548	0.548
Obs	85741	84739	84628	83482	83482	83482

Notes: This table reports the effects of the Nationwide Battle to Prevent and Control Pollution (NBPCP) on MCB spreads. 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. *AQI* is the Annual Air Quality Index at city level in 2017. *Industrial SO2* represents annual industrial sulfur dioxide emissions at city level in 2017. *Industrial sewage* represents annual industrial wastewater emissions at city level in 2017. *Industrial 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. All regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses are clustered at city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A8: GSA and MCB Spreads: AAA-Rated Bonds

	Spread			
	(1)	(2)	(3)	(4)
NNR × Post	0.189**	0.163**	0.161**	0.171**
	(0.081)	(0.077)	(0.077)	(0.077)
Controls	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.664	0.677	0.685	0.687
Obs	17920	17920	17920	17676

Notes: This table reports the regression results of the impact of GSA on MCB spreads, excluding bonds with credit ratings below AAA in Table 3. The dependent variable is calculated as the difference between the MCB yield and CDB yield on the same day and of the same maturity. Specifically, we use the spread on the last trading day of each quarter in Column (1) (the same as that in Table 3), and the measures used are the quarterly median of spreads, the quarterly mean of spreads, and the quarterly trading-volume-weighted spreads in Columns (2) - (4), respectively (as explained in Section 4.2). *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. Regressions include year-quarter and issuer fixed effects, as well as all controls defined in Table 3. 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 Public Financing Demand

Dependent	MCB issuance dummy	MCB issuance amount	Growth rate of LGFV debt	Growth rate of LGFV interest-bearing debt
	(1)	(2)	(3)	(4)
NNR × Post	-0.040	-1.615	-1.291	-8.404
	(0.030)	(1.291)	(3.710)	(6.338)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.372	0.775	0.181	0.154
Obs	2437	2437	2437	2437

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 total amount of new MCBs issued by a city in that year (in billion RMB yuan). *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 (in percentage). *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 (in percentage). *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 2017 and zero otherwise. Regressions include year and city fixed effects, as well as the city-level control variables (i.e., *city pre-shock var.*×*Post* used in Table 3). Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A10: GSA and Local Political Risk

Panel A: GSA and local political turnover

Dependent	Turnover dummy	
	Municipal CPC secretary	Mayor
	(1)	(2)
NNR × Post	-0.025	0.042
	(0.032)	(0.028)
Controls	Yes	Yes
Year FE	Yes	Yes
City FE	Yes	Yes
Adjusted R^2	0.093	0.115
Obs	2725	2725

Panel B: GSA and MCB spreads: local political risk

Dep.var	Spread	
	Municipal CPC secretary	Mayor
	(1)	(2)
NNR × Post	0.237***	0.236***
	(0.081)	(0.079)
NNR × Post × In the first 2 years of tenure	0.004	0.009
	(0.060)	(0.064)
Other terms of triple diff.	Yes	Yes
Controls	Yes	Yes
Year-quarter FE	Yes	Yes
Issuer FE	Yes	Yes
Adjusted R^2	0.562	0.561
Obs	87885	87885

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 in both panels. Panel A reports the effects of GSA on local political turnover at the city-year level. The dependent variable in Panel A is a dummy variable that equals one if the corresponding city's leading official changes in that year. *Post* in Panel A is a dummy variable that equals one in and after 2017 and zero otherwise. Regressions in Panel A include year and city fixed effects, as well as the city-level control variables (i.e., *city pre-shock var.*×*Post* used in Table 3). Panel B reports the differential impacts of GSA during specific stages of the official's tenure. The dependent variable in Panel B is MCB spread. *Post* in Panel B is a dummy variable that equals one 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 complete years of the corresponding official's term and zero otherwise. Regressions in Panel B include all required components of the triple-difference model, year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses of both panels are all clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A11: GSA and Biodiversity Improvement: IUCN Measure

Dependent	Species richness - Mean	Species richness - Rank
	(1)	(2)
NNR × Post	11.930***	-10.851***
	(3.789)	(3.429)
Year FE	Yes	Yes
City FE	Yes	Yes
Adjusted R^2	0.961	0.950
Obs	624	624

Notes: This table reports the city-year-level regression results of the effects of GSA on local biodiversity using IUCN Red List data. *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 in 2022 and zero in 2017. The dependent variable is the average number of species potentially occurring per grid in the city in Column (1), and the city's species richness ranking according to this average in the corresponding year in Column (2). Regressions include year and city fixed effects. Standard errors in parentheses are clustered at the city level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table A12: GSA and MCB Spreads: Information Asymmetry

	Spread	
	(1)	(2)
NNR × Post	0.247**	0.245**
	(0.108)	(0.105)
NNR × Post × High newspaper coverage	-0.014	0.006
	(0.108)	(0.107)
Other terms of triple differences	Yes	Yes
Controls	Yes	Yes
Year-quarter FE	Yes	Yes
Issuer FE	Yes	Yes
Adjusted R^2	0.561	0.561
Obs	87885	75184

Notes: This table reports the heterogeneous effects of GSA on MCB spreads in information asymmetry. 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. *High newspaper coverage* is a dummy variable that equals one if NNRs managed by an NNR municipality were covered by the top 10 comprehensive newspapers by average circulation in 2016. Column (1) employs the full sample. Column (2) excludes cities that owned NNR and only covered by one source of the top 10 comprehensive newspapers by average circulation in 2016, for robustness. Regressions include all required components of the triple-difference model, year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A13: GSA and MCB Spreads: Biodiversity Improvement

	Spread			
	Birds species observed		species - IUCN measure	
	(1)	(2)	(3)	(4)
NNR × Post	0.186**	0.193**	0.206**	0.226***
	(0.085)	(0.075)	(0.084)	(0.084)
NNR × Post × High bio improvement	0.113	0.191	0.129	0.044
	(0.112)	(0.185)	(0.111)	(0.098)
Other terms of triple differences	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.560	0.561	0.561	0.561
Obs	86039	86039	87885	87885

Notes: This table reports the heterogeneous effects of GSA on MCB spreads in biodiversity improvement. 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. *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. In Column (1) and (3)-(4), the level of biodiversity improvement is measured by the absolute increase in the number of species following GSA for each NNR municipality (i.e., the number of species after GSA - that before GSA); In Column (2), the level of biodiversity improvement is measured by the relative increase in number of species following GSA for each NNR municipality (i.e., (the number of species after GSA - that before GSA) / that before GSA). Consistent with the description in Section 6.1, the number of species is calculated from the city's value of bird species observed based on birdwatching data in Columns (1)-(2), the city's value of average species richness based on IUCN Red List data in Column (3), and the city's rank of average species richness based on IUCN Red List data in Column (4). Regressions include all required components of the triple-difference model, year-quarter and issuer fixed effects, as well as all controls defined in Table 3. Standard errors in parentheses are clustered at the city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A14: GSA and MCB Spreads: Weighted Least Square Regression according to pre-GSA city debt level

	Spread			
	(1)	(2)	(3)	(4)
NNR × Post	0.328**	0.379***	0.321***	0.350***
	(0.145)	(0.127)	(0.099)	(0.092)
Year-quarter FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes
Bond controls	No	Yes	No	Yes
City pre-shock var. × Post	No	No	Yes	Yes
Adjusted R^2	0.419	0.505	0.429	0.513
Obs	87600	87600	87600	87600

Notes: This table reports the regression results of the impact of GSA on MCB spreads using weighted least square estimation. The weighting factor is the city-level average value of LGFV interesting-bearing debts from 2013 to 2016. 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. Regressions include year-quarter and issuer fixed effects. Bond controls contain (ln)bond issuing amount, bond maturity, bond rating, issuer rating, and whether the bond is option-embedded, guaranteed, and traded on exchange. City pre-shock variables include (ln)GDP, (ln)GDP per capita, GDP growth rate, the proportion of tertiary sector in GDP, (ln)population, population growth rate, (ln)nighttime light intensity, (ln)fixed investment, and (ln)housing price at city level in 2013. Detailed definitions of control variables are presented in Table A1. Standard errors in parentheses are clustered at city level. ***, **, and * indicates significance at the 1%, 5%, and 10% level, respectively.

Table A15: Additional Local Public Debt Costs and Corresponding Economic Significance

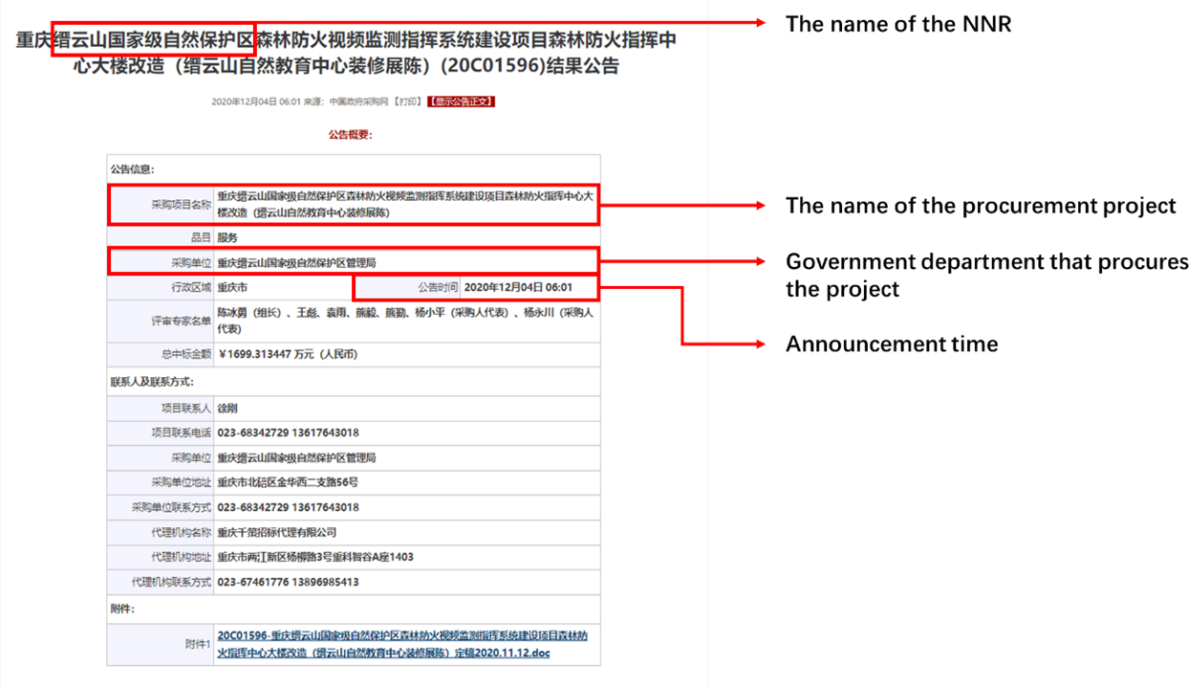
Scenario A: China bears the gap in biodiversity financing according to its share of global species (6.4%)				
Scenario B: China bears the gap in biodiversity financing according to its share of global land area (7%)				
Scenario C: China bears the gap in biodiversity financing according to its share of global GDP (18.5%)				
Year	2018	2019	2020	2021
Additional financing costs for MBC markets (Billion dollars)	0.96	5.25	11.54	21.44
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)		45.5	45.5	45.5
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
The proportion of additional financing costs in China's biodiversity financial gap in Scenario A (%)		11.54	25.36	47.12
The proportion of additional financing costs in China's biodiversity financial gap in Scenario B (%)		10.55	23.19	43.08
The proportion of additional financing costs in China's biodiversity financial gap in Scenario C (%)		3.99	8.77	16.30

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

B Additional Materials on Institutional Background

B.1 Several examples of government procurement on NNRs

Figure B1: Government Procurement Contract Related to NNR (1)



Notes: 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.

FIGURE B2: GOVERNMENT PROCUREMENT CONTRACT RELATED TO NNR (2)



Notes: 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.

FIGURE B3: GOVERNMENT PROCUREMENT CONTRACT RELATED TO NNR (3)



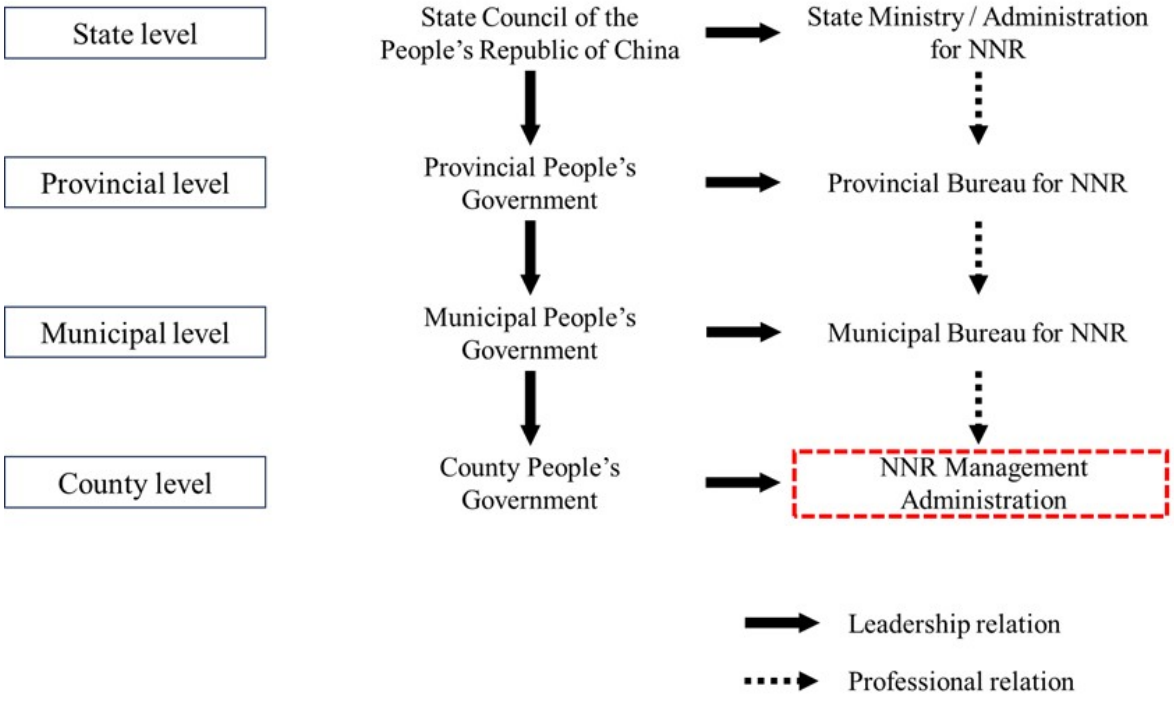
Notes: This government procurement contract is related to the vegetation restoration project in the Xiadu area of the Yangtze Alligator National Nature Reserve in Anhui. The procurement aims to restore the vegetation within the reserve, providing better living conditions for the Yangtze alligator and 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.

B.2 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 relation" in which superior agencies supervise the daily affairs of agencies at lower levels in carrying out their defined functions.

For the administration committee of the 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 the nature reserve organizations can be illustrated in Figure B4 below.

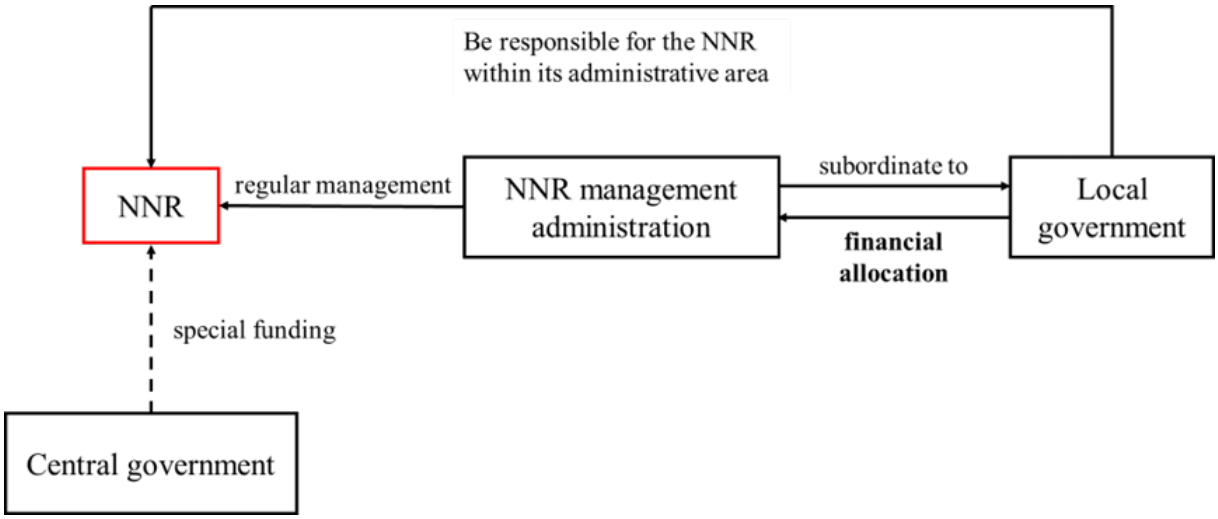
FIGURE B4: INSTITUTIONAL STRUCTURE ARRANGEMENTS FOR NNRS



B.3 Sources of NNR Funds

Consistent with the materials in Section 2 and Figure B4, 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 modest. Figure B5 presents the institutional arrangement features pertaining to the funding of NNRs:

FIGURE B5: THE GENERAL 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 the National Forestry and Grassland Administration of PRC.

According to China Forestry and Grassland Statistical Yearbook, the total investment in the "Nature 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 deputy 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. As a result, the national conservation management policies at the grassroots level suffer significantly from 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 the 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 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 RMB yuan in subsidies in 2022 (Figure B6).

FIGURE B6: 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

B.4 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.

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 find 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 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.*

It should be noted that changes in political incentives are to improve the implementation of local authorities on biodiversity conservation in NNRs, not necessarily associated with an overall significant increase in local political risk, as we discussed in Section 5.4.

B.5 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 the 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 (those in which no individual is allowed to enter) 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 consisted 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 GSA 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?*

B.6 A Case for the Jinyun Mountain NNR in Chongqing: Timeline of GSA Implementation

The response of Chongqing municipal government to the GSA requirements is marked by three distinct features: First, there was a delayed commencement, with actions being taken at least one year after GSA initiation. Second, the government undertook significant measures, particularly in managing the Jinyun Mountain NNR, indicating a firm commitment to GSA's mandates. Third, the expenditure and rectification work is a progressive process rather than a one-time task.

Below is a timeline detailing how the central government's actions have driven the Chongqing municipal government's initiatives following the launch of GSA.

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.

From 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 supervise the rectification work. The Chongqing government convened 33 meetings to deploy rectification work and issued the "Comprehensive Plan for Ecological and Environmental Remediation in Jinyun Mountain Nature Reserve."

In August 2018, 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 nature reserves. Officials from Shapingba District, Beibei District, and the Chongqing Forestry Bureau were

among those summoned for the 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 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 was 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 was actively working to establish a regular inspection institution specifically tailored to oversee and maintain the integrity of the NNR.

Here we summarize the key stages of GSA in Jinyun Mountain NNR.

- **Wait-and-see stage**
  - **July 2017**
    The declaration of GSA by Ministry of Ecology and Environment (MEE).
  - **July 2017 $\sim$ Dec 2017**
    Seven ministries jointly organized and executed GSA 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, Chongqing government issued the "Comprehensive Plan for Ecological and Environmental Remediation in Jinyun Mountain Nature Reserve."
  - **Aug 2018**
    Demolished illegal structures. Chongqing government demolished illegal structures in a horse farm inside the NNR.
  - **Sept 2018**
    Local government officials were summoned for meeting. MEE summoned the responsible government departments regarding the encroachment and damage to natural reserves.
  - **Feb 2019**
    Initiation of the relocation of residents. Chongqing government initiated the relocation of indigenous residents inside the NNR.
  - **June 2019**
    Start comprehensive improvement project. The comprehensive improvement project of the Jinyun Mountain NNR 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 NNR 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, Beibei government (a county-level government under Chongqing municipality) had invested a total of 2.75 billion yuan in the NNR.
  - **2021 $\sim$ 2022**
    (1) Continue to implement ecological restoration projects inside the NNR. (2) Complete the overall plan for the Jinyun Mountain NNR in Chongqing (2021-2030). (3) Establish the regular inspection institution for nature reserves.