From Fine to Feathers: Enforcement Stringency, Protectionism, and Biodiversity

Panyu Li[1], Yuchen Xu[2], Luping Yu[3]

Abstract

Using birdwatching records and staggered reforms that enhance the independence of China's Environmental Protection Bureaus (EPBs) during 2003-2019, this paper underscores the importance of policy enforcement stringency for biodiversity conservation. We find that greater EPB independence increased bird species richness by 22–32% and bird abundance by 35–46%. The reforms reduced local protectionism, leading to more penalties on privately owned enterprises and incentivizing them to invest in green R&D. However, state-owned enterprises continue to avoid regulatory scrutiny due to persistent central protectionism. Our findings highlight the substantial ecological costs of weak enforcement resulting from incomplete administrative independence.

Keywords: Bird diversity, environmental enforcement, administrative independence, local protectionism, central protectionism

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[1] Beedie School of Business, Simon Fraser University, 8888 University Drive Burnaby, British Columbia, Canada, author email: panyu_li@outlook.com (PhD candidate).
[2] Business School, University of New South Wales, Kensington, New South Wales 2052, Australia, author email: yuchen.xu@unsw.edu.au (corresponding author).
[3] Faculty of Business Administration, University of Macau, E22 Avenida da Universidade, Taipa, Macau, China, author email: lupingyu@um.edu.mo.

1. Introduction

The Earth does not belong solely to humans. However, several episodes of intense economic expansion have led to profound biodiversity loss, including large-scale species extinctions,[4] with serious and far-reaching consequences for humanity (Feir, Gillezeau and Jones 2024, Frank and Sudarshan 2024).[5] In addition to pollution and climate risks, biodiversity loss introduces unique risks and challenges for economic and financial markets (Giglio et al. 2023, Hoepner et al. 2023, Karolyi and Tobin-de la Puente 2023). While recent research has begun to address these issues, it has primarily focused on investor recognition of firm exposure to biodiversity risks (Garel et al. 2024), as well as the financial implications of biodiversity risks or conservation policies (e.g., Giglio et al. 2024, Chen et al. 2024). Relatively little research has explored real variations in biodiversity or methods to reverse biodiversity loss.

Governments worldwide have implemented extensive environmental regulations and policies to combat environmental degradation, including biodiversity loss.[6] Beyond policy creation, the stringency of enforcement critically influences policy effectiveness.[7] For firms, the anticipated rigor of policy enforcement significantly influences how they perceive penalty risks and their resulting conservation efforts (Blundell, Gowrisankaran, and Langer 2020). Policy enforcement stringency, therefore, has implications for both financial and environmental outcomes (Choy et al. 2024). This

[4] For reference, in "Sapiens: A Brief History of Humankind" (2015), Harari discusses how human economic activities have significantly impacted species extinction throughout history. Dating back to the Cognitive Revolution (c. 70,000 BCE), humans' advanced hunting skills led to the extinction of large animals, such as the woolly mammoth, woolly rhinoceros, and giant deer in Europe, as well as megafauna in Australia and North America. Similarly, the Agricultural Revolution (c. 10,000 BCE) caused habitat changes and biodiversity loss due to farming practices. The Unification of Humankind (c. 1st century) intensified environmental degradation as human societies expanded. The Scientific Revolution (c. 16th century) and the Industrial Revolution (c. 19th century) further accelerated pollution and the overexploitation of natural resources, leading to increased species extinction rates. Harari emphasizes that these patterns of extinction are direct consequences of humanity's relentless expansion and exploitation of ecosystems. The past decade has also seen a dramatic increase in the number of endangered species, with over 44,000 species at risk as of 2023. See Statista, "Biodiversity Loss - Statistics & Facts", https://www.statista.com/topics/11263/biodiversity-loss/#editorsPicks.

[5] Estimates suggest that degrading ecosystems could potentially trigger a decline of US$2.7 trillion in global GDP by 2030. See United Nations Development Programme, "COP15: UN Biodiversity Conference," https://www.undp.org/events/cop15-un-biodiversity-conference

[6] For example, governments worldwide have recently committed to addressing biodiversity loss together. At COP15 in 2022, a total of 188 governments agreed to the Kunming-Montreal Global Biodiversity Framework and committed to addressing the ongoing loss of terrestrial and marine biodiversity.

[7] For example, during the 2008 Olympics, prior concerns about Beijing's air quality prompted the city to implement strict environmental enforcement on industrial production and construction activities. Reportedly, the air pollution index in Beijing dropped from an average of 102 before the Olympic Games to an average of 55 during the Olympics, representing a decline of approximately 50%. However, this improvement was temporary, and air quality returned to previous levels after the Olympic Games concluded (Chen et al. 2013).

paper aims to gauge the costs to biodiversity when environmental policy enforcement is weak. We also investigate the underlying mechanisms and their implications for different types of firms.

The Chinese context provides unique exogenous variation in the enforcement stringency of environmental regulations. Driven by the country's political tournament regime (Li and Zhou 2005) and fiscal federalism (Qian and Roland 1998), local officials in China have been heavily incentivized to prioritize economic growth targets over the past few decades (Lo, Fryxell and Wong 2006, Liu et al. 2020). This relentless focus on economic development has led to lenient enforcement of environmental regulations at the local level (Ma and Ortolano 2000, Wang et al. 2003), compromising environmental sustainability and resulting in excessive pollution and significant damage to ecosystems (Yu et al. 2023).[8] In response, the Chinese central government introduced "vertical management reform," which increased the administrative independence of local Environmental Protection Bureaus (EPBs).[9]

Prior to the reform, local EPBs were under the control of local governments, creating inherent conflicts of interest in enforcing environmental laws since local governments prioritized economic development. In the early 2000s, cities began implementing the reform, which transferred local EPBs' enforcement authority to higher administrative levels, effectively removing local government control. Centralizing regulatory oversight and increasing local EPBs' administrative independence in this way has enabled more rigorous and impartial environmental law enforcement. We leverage the staggered city-level EPB reforms between 2003 and 2019 and employ a difference-in-differences (DiD) approach to evaluate whether the reforms have increased environmental law enforcement stringency and to investigate how more stringent enforcement may influence biodiversity outcomes.

Because overall biodiversity is multidimensional and difficult to measure, we focus on avian diversity to capture variation in biodiversity. Scientifically defined, biodiversity encompasses the diversity of species, genetic variability within species, and variety among ecosystems and ecological processes. Although it is challenging to construct sensitive measures that capture variation in general biodiversity both over time and across regions, birds are among the best ecological indicators. They are

[8] See Forbes (May 1, 2023), "Beijing Says It Cares About Climate but Prioritizes Growth," https://www.forbes.com/sites/miltonezrati/2023/05/01/beijing-says-it-cares-about-climate-but-prioritizes-growth/.

[9] See Figure 4 for a schematic diagram illustrating the reform.

highly sensitive to habitat changes and pollutants, making them effective proxies for assessing ecosystem health.[10] Furthermore, birds contribute to crucial ecosystem services, such as pollination, seed dispersal, and pest control, which makes their diversity essential for maintaining ecological balance.

To capture changes in bird diversity, we compile all available birdwatching records from both *eBird.com*, a global birdwatching platform, and *birdreport.cn*, a local Chinese birdwatching platform. We develop two avian diversity indicators: 1) bird species, which is the number of unique bird species observed within each city-year and serves as a proxy for species diversity, and 2) bird observation rate, which is the average number of birds observed per hour in each birdwatching event and serves as a proxy for bird abundance. To address concerns regarding the amateur nature of birdwatching activities and their potential limitations in observing all species, we cross-verify bird species' zoogeographical distribution with scientific monographs. These monographs determine bird distributions using more specialized and scientific methods, such as field photography, videography, audio recordings, satellite telemetry, and bird behavior recorders. Our analysis reveals that the *eBird* and *birdreport* data accurately cover over 80% of species, with coverage increasing to 85–90% in most urban areas.

Using the staggered DiD strategy and controlling for various city-level and birdwatching-level covariates, our baseline findings show that more stringent environmental enforcement led to significant increases in bird diversity. The effect magnitudes are striking: cities saw an increase of 23.8 additional bird species (a 32.3% increase) and 29.4 more birds observed per hour (a 46.1% increase) following the Chinese EPB reforms. This post-reform increase in bird diversity can be interpreted as a lower-bound estimate of the costs of weak environmental regulatory enforcement, which has contributed to biodiversity loss.

To provide a concrete example, Figure 1 illustrates the expansion of Little Forktail (*Enicurus scouleri*) before and after EPB reforms. The figure depicts cities where Little Forktail was observed in 2014 (Panel B) and in 2018 (Panel C), alongside cities that underwent the EBP reform during 2015–

[10] See CitizenScience.gov, "eBird bird data," https://www.citizenscience.gov/ebird-bird-data/

2018. Little Forktail expanded its range significantly between 2014 and 2018, particularly into cities that implemented the reform during this period.

[Figure 1 about here]

To assess the channel and quantify variation in enforcement stringency, we explore Environmental Protection Administrative penalties imposed on Chinese enterprises. Although penalties alone are an ambiguous indicator of enforcement stringency—fewer penalty cases can signify either weak enforcement or genuinely good environmental quality—the DiD framework controls for city and year fixed effects, enabling a robust comparison of enforcement outcomes before and after the EPB reforms were implemented. The results indicate significant effects of the reforms: post-reform, the number of penalty cases increased by 153.5%, and total fines rose by 144.7%. On average, fine amounts increased by 7.1 million yuan (RMB) at the city level. Combined with the estimated preservation of 23.8 bird species post-reform, this increase suggests that each additional 1 million yuan in fines resulted in the conservation of approximately 3.4 bird species.

These findings underscore the strong sensitivity of avian diversity to enforcement actions and emphasize the critical role of stringent policy enforcement in biodiversity protection. To strengthen the causal interpretation between enforcement stringency and avian diversity, we divide cities into "stricter" (above median) and "looser" (below median) enforcement categories based on the magnitude of penalty increases surrounding EPB reform implementation. The results show that improvements in avian diversity are concentrated in the stricter cities.

We also evaluate enforcement penalty increases across air, water, solid waste, and industrial noise pollution to further investigate the types of pollutants affecting biodiversity. This analysis provides new insight into the green finance literature, which has predominantly focused on air and water pollution (e.g., Greenstone and Hanna 2014, Dasgupta, Huynh and Xia 2023). We find that solid waste, alongside air and water pollution, plays a critical role in biodiversity outcomes. These findings highlight the importance of considering a broader range of pollutants in biodiversity and sustainable finance research, suggesting that policymakers and ESG investors should account for the impacts of various pollutants beyond air and water when evaluating environmental risks and sustainability practices.

In Section 4, we examine which firms bear the conservation costs (higher fines) following the policy enforcement change. Reframing the question, we aim to identify which firms benefited from regulatory leniency before the EPB reforms and thus contributed disproportionately to biodiversity loss. Drawing from the literature on judicial and administrative independence (e.g., Liu et al. 2022), we analyze the effects of the reform—designed to enhance the administrative independence of local EPBs—from the perspective of both local and central protectionism in China.[11] Our findings show that post-reform enforcement has disproportionately regulated local and privately owned enterprises (POEs, including both listed and unlisted companies), while state-owned enterprises (SOEs) have not faced a significant increase in penalties. These results suggest that enhancing administrative independence has effectively curbed local protectionism, benefiting biodiversity by imposing stricter regulations on local firms, which now bear the increased costs of conservation efforts. However, central protectionism remains a significant challenge because SOEs are major contributors to pollution, and they continue to evade meaningful enforcement. This disproportionate effect indicates that while the reform has made progress in reducing local protectionism, further measures are necessary to address the privileged status of SOEs and mitigate their ongoing environmental impact.

Lastly, we examine firms' conservation efforts in response to enhanced environmental enforcement.[12] We use green patents as a proxy for firms' environmental innovation and sustainability efforts.[13] Our analysis reveals that local and privately owned firms show a significant increase in green patent applications post-reform, reflecting their proactive efforts to hedge stricter environmental regulations. However, SOEs do not exhibit a comparable increase in green patents. This discrepancy

[11] Local protectionism arises when local governments shield firms that create local economic growth and tax revenue, often resulting in looser regulatory enforcement; central protectionism refers to state-owned enterprises (SOEs) receiving preferential treatment due to their connections with the central government. By increasing administrative independence of EPBs from local governments, local firms stand to lose regulatory leniency, while SOEs remain relatively insulated due to their political connections to the central government.

[12] As reported in the appendix, we found that while overall pollution levels declined, output was not significantly affected, suggesting that firms may be investing in green initiatives to reduce emissions while maintaining production levels.

[13] Patents data is available for all firms, including unlisted firms, which allows for a more comprehensive analysis of green investments across sectors.

points again to the persistent challenge of central protectionism: SOEs face fewer environmental regulations and are less motivated to invest in conservation efforts.

This research contributes to recent but emerging literature that integrates biodiversity into economic and finance frameworks. Beyond pollution, biodiversity loss has profound and far-reaching consequences for humanity (Feir et al. 2024, Frank and Sudarshan 2024), introducing unique challenges for economic and financial markets (Giglio et al. 2023, Hoepner et al. 2023, Karolyi and Tobin-de la Puente 2023). Accordingly, investors recognize biodiversity risks (Garel et al. 2024), and thus asset prices and financing costs react to biodiversity risks (Cherief, Sekine and Stagnal 2022, Xin et al. 2023, Hoepner et al. 2023, Coqueret, Giroux and Zerbib 2025) and conservation policies (Chen et al. 2024). Studies also construct frameworks on how to leverage finance for conservation efforts (Flammer, Giroux and Heal 2025). Yet, understanding the extent to which economic activities have harmed biodiversity (Meng et al. 2024) is crucial for creating and enforcing conservation policies that can protect and improve biodiversity. Furthermore, examining which types of firms incur the economic costs of addressing biodiversity issues and which can evade them enhances our understanding of the conservation policy framework. By examining the dynamics of government actions, firm behavior, and biodiversity, this research underscores the importance of policy enforcement effectiveness—beyond investor preferences—in shaping firm conservation practices.

Second, we engage the extensive green finance literature.[14] Extant sustainable finance and ESG research largely focuses on the environmental considerations of firms and investors (e.g., Hartzmark and Sussman 2019, Krueger, Sautner and Starks 2020, Bolton and Kacperczyk 2021, Xu and Kim 2022, Sautner et al. 2023, Starks 2023, Edmans, Gosling and Jenter 2024), with far less attention given to the role of environmental regulation, particularly the effectiveness of enforcement. A significant motivation for firms to adopt green practices also stems from the implementation of environmental laws and policies (Greenstone 2002, Blundell et al. 2020, Liu, Tan and Zhang 2021, Dasgupta et al. 2023,

[14] Despite the breadth of this literature, existing research on ESG can be broadly categorized in relation to several fundamental questions: who considers ESG (which investors and firms), why they consider it (their motivations), how they integrate ESG into decision-making, and what the outcomes of such integration are (particularly regarding financial implications). A central debate within this literature is the "value vs. values" question (Starks 2023)—whether investors and firms should approach ESG and CSR as matters of social responsibility (e.g., Bénabou and Tirole 2010) or from a financial perspective (e.g., Houston and Shan 2022, Duchin, Gao and Xu 2024).

Ramadorai and Zeni 2024), as these regulations introduce additional risks of penalties and litigation (Wu, Luo and You 2024) and consequent increased financing costs (Bartram et al. 2022, Choy et al. 2024). However, enforcement of environmental regulations is inconsistent and likely influenced by factors such as firms' political connections (Heitz, Wang and Wang 2023). Inconsistent enforcement is particularly relevant for economically developing and geographically large countries such as China and India, where less stringent enforcement of environmental policies has consequences not only for pollution (He, Wang and Zhang 2020), but also for broader concerns, such as infant mortality (Greenstone and Hanna 2014) and trade (Hering and Poncet 2014). We contribute to the green finance literature by assessing the real impact of variations in environmental enforcement stringency on firm behavior and biodiversity.

Finally, our study addresses the implications of administrative and judicial independence in policy effectiveness. Imperfections in these policy enforcement systems can lead to local protectionism (Hay and Shleifer 1998, Liu et al. 2022). As existing research has highlighted, judicial imperfections and local protectionism negatively impact economic growth (Fisman and Gatti 2002, Bai et al. 2004, Gong 2004, Ponticelli and Alencar 2016, Barwick, Cao and Li 2021, Zhou et al. 2021, Li 2022, Liu et al. 2022), including firm pollution (Stern 2011, Kahn et al. 2015, Zhang, Chen and Guo 2018, Axbard and Deng 2024, Kong and Liu 2024, Wang and Ye 2024). In China, administrative and judicial systems are often influenced by political connections (Gong 2004), contributing to both local (Bai et al 2004) and central protectionism (Eaton and Kostka 2017). In recent decades, the Chinese central government has implemented decentralization reforms across various departments to increase administrative and judicial independence (Xu 2011, Wang 2021, Cao, Liu and Zhou 2023). We study the efficacy of decentralization reforms in China and contribute empirical evidence to the literature that highlights the effectiveness of increasing the administrative independence of environmental bureaus as a strategy to reduce local protectionism and safeguard biodiversity.

Overall, our paper underscores the role of stringent environmental policy enforcement in mitigating the adverse impacts of corporate activities on ecosystems. Understanding the complex interactions between regulators, firms, and non-human species is crucial for developing policies that balance economic growth with environmental sustainability. Such policies ensure that economic objectives are pursued without compromising biodiversity or contributing to ecosystem degradation. Judicial and administrative independence, as we demonstrate, plays a vital role in ensuring the effective implementation of environmental regulations.

2. Data and Sample

Our empirical analyses rely on panel datasets at the Chinese prefectural city level, spanning from 2003 to 2019. We start our sample from 2003 because the environmental penalty records required for channel analysis, along with key annual city-level control variables (e.g., green space ratio), were systematically recorded starting in 2003, with only three cities undergoing the EPB reform before 2003. We conclude our sample period in 2019 because the pandemic caused production suspensions and disruptions in government revenues that could affect both firm pollution and environmental regulation enforcement. The full sample comprises 277 cities from 31 provinces for which we collected the timing of EPB reform implementation between 1994 and 2024.

2.1 Avian diversity

We use avian diversity as a measure of biodiversity, given that birds are highly sensitive to habitat changes and pollutants, making them effective proxies for assessing ecosystem health. Avian diversity is also crucial for maintaining ecological balance, as birds provide essential ecosystem services, such as pollination, seed dispersal, and pest control.

To capture avian diversity, we utilize birdwatching records sourced from both *eBird.com* and *birdreport.cn*. eBird is a global platform managed by the Cornell Lab of Ornithology, allowing observers worldwide to submit bird sighting data across various times and locations. Similarly, birdreport is a Chinese platform that enables local birdwatchers to log their observations. [15]

Both datasets report core variables for each birdwatching event (also called a checklist), including the names of the observed bird species, the count of birds observed, the location of the

[15] *eBird*'s records trace back to the mid-19th century. Currently, millions of bird observations are logged monthly into its central database at the Cornell Lab of Ornithology. Scientists, land managers, and birdwatchers utilize this information to document changes in bird distributions, to identify bird populations requiring conservation, and to discover new species. Similarly, *birdreport.cn* is a Chinese platform that includes records dating back to the 1980s. For our sample period, we found a comparable volume of birdwatching records on both platforms.

birdwatching activity, a unique birdwatching account ID, and the “effort hours,” which we obtain by calculating the duration of the observation from the recorded start and end times. eBird further reports the distance traveled during the observation period in km, referred to as “effort distance,” and the number of observers in each event. We compile all available birdwatching records in China and filter the data by excluding records that meet the following criteria: 1) event locations (latitude and longitude) that cannot be associated with a Chinese city, 2) missing data on the number of birds observed or effort hours, 3) effort hours less than one hour or more than twelve hours, and 4) records with zero birds observed or more than 50,000 birds observed. After filtering, we obtain approximately 40,000 unique birdwatching events from 2003 to 2019.

We construct two metrics to measure avian diversity: bird species richness and bird observation rate. Bird species richness is defined as the total number of unique bird species observed within a given city-year across all birdwatching events. This metric captures the diversity of bird species present in the area.[16] Bird observation rate, which we construct at the event level, serves as a measure of bird abundance and is defined as the number of birds observed per hour. To address the presence of outliers, we winsorize each metric by city at the 5% level.

[Table 1 about here]

Table 1 presents the summary statistics. Among the 1,519 city-year observations with birdwatching records, an average of 73.7 unique bird species is observed per city-year. For each birdwatching event, an average of 63.8 birds is observed per hour. Figure 2 illustrates the spatial distribution of the 1,586 unique bird species observed from 2003 to 2019, showing that bird species are not highly concentrated in specific regions. Both the southwest and eastern coastal regions exhibit high species diversity.

[Figure 2 about here]

[16] The basic assumption is that if there are sufficient birdwatching events, the majority of bird species (if not all) should be observed.

To address concerns about the amateur nature of birdwatching and its potential limitations in capturing all species, we cross-verify bird species' zoogeographical distributions using scientific monographs. Specifically, we reference the three editions of *A Checklist on the Classification and Distribution of the Birds of China* (Zheng 2005, Zheng 2011, Zheng 2017), which document all bird species in China and their occurrences across the country's 18 zoogeographical regions. These monographs rely on specialized and scientific observation and categorization methods, including field photography, videography, audio recordings, satellite telemetry, and bird behavior recorders. Zhang et al. (2022) provide a description of these monographs and open-access datasets of the bird species lists.

We assess the coverage rate by comparing two datasets for each zoogeographical region: the complete list of bird species from Zheng's monographs (Zheng 2005, Zheng 2011, Zheng 2017) and the list of bird species observed by amateurs on eBird and birdreport. We then calculate the percentage of species in Zheng's list that were also reported on eBird and birdreport. As shown in Figure 3, our analysis reveals that birdwatching data accurately covered 80.7% of species, with coverage increasing to 85–90% in most urban areas.

[Figure 3 about here]

2.2 Environmental Protection Bureau reform

In China, the Environmental Protection Bureaus (EPBs) are responsible for monitoring environmental quality, enforcing regulatory compliance, and implementing policies to prevent and control pollution. These bureaus operate at national, provincial, city, and county levels. Prior to reforms, each level of government had control over its corresponding EPB: county governments managed county-level EPBs, while city governments oversaw city-level EPBs.

In 1994, China initiated a trial of "vertical management reform" for EPBs, aiming to enhance the effectiveness of environmental monitoring and enforcement by reducing the influence of local governments, which often prioritize local economic growth.[17] This reform increased the administrative

[17] The objective of the EPB reform was explicitly outlined by the Ministry of Ecology and Environment of the People's Republic of China: "For a long time, China has implemented a territorial-based environmental management system, which has led to many insurmountable problems. For instance, some local governments prioritize development over environmental protection, focusing on economic growth while neglecting environmental concerns... … Environmental responsibilities are not

independence of local EPBs by shifting control from county governments to higher city-level EPBs, enabling the city EPB to assume responsibility for the funding, staffing, and overall management of county-level EPBs.

[Figure 4 about here]

Figure 4 presents a schematic diagram of this reform. Prior to the reform, the EPB control structure had been "horizontal;" following the reform, the EPB system transitioned to an independent "vertical" structure. Although this reform did not alter the physical structure of EPBs, it significantly changed their control mechanisms, which influenced incentives within the local administrative system. This change enhanced the administrative independence of the EPBs and was therefore expected to improve the effectiveness of regulatory enforcement.

We manually collect and verify the timing of the implementation of the reform for each city from official government website announcements and through direct calls to government offices. Our final sample includes timing data for 277 prefecture-level cities that implemented reforms between 1994 and 2024. To avoid measurement biases, cities for which we were unable to determine reform timing are omitted from our sample. During our sample period (2003–2019), a total of 230 cities underwent the reform. The 44 cities that implemented reform between 2020 and 2024 remain untreated in our sample period.

2.3 Environmental penalties

EPBs play a critical role in overseeing firm-level emissions, assessing environmental impact, and promoting sustainable practices to protect ecosystems and public health. A key component of their enforcement is the issuance of environmental penalties—administrative sanctions imposed on firms that violate environmental protection laws. These penalties establish environmental administrative responsibilities and can include fines, production stoppages, and other specific measures. Penalties are

properly enforced, and the responsibilities of local governments often fall on local environmental protection departments. The existence of these issues seriously undermines the uniformity, authority, and effectiveness of environmental regulation, hindering the modernization of the national environmental governance system and its capabilities… … According to the original intent of the institutional design, the vertical management reform of environmental protection aims to strengthen the implementation of environmental protection responsibilities by local governments and their relevant departments. It seeks to resolve the interference of local protectionism in environmental monitoring, supervision, and law enforcement ..." (Ministry of Ecology and Environment of the People's Republic of China, 2016) typically issued for violations across four main pollution categories: air, water, solid waste, and industrial noise. Through these efforts, EPBs aim to curb pollution and encourage responsible corporate behavior.

We obtain data on the universe of environmental penalties imposed on Chinese enterprises since 2003 from CnOpenData's China Enterprise Environmental Protection Administrative Penalty Data. The dataset reports key variables for each penalty, including the company name, penalty date, penalty content (fine amount, orders, etc.), reasons for punishment, and the issuing EPB. Based on this information, we construct two variables: the number of penalties and the total amount of fines in million yuan (RMB) for each city-year. As shown in Table 1, each city-year has an average of 84.1 penalties, with a total fine amount exceeding 4.9 million RMB. When comparing the pre-reform and post-reform periods, on average, the number of penalties increased from 56.8 to 288.6 per city-year, and the total fine amount rose from 3.2 million to 18.1 million RMB per city-year. These numbers indicate that EPB reform has substantially impacted environmental enforcement.

To further refine our analysis of heterogeneous effects, we collect additional firm-specific information for all firms penalized during our sample period from *tianyancha.com,* which is a leading platform that aggregates comprehensive information on enterprises in China. Focusing on firm registration locations and ownership structures, we categorize firms into "local" or "non-local" based on whether their registration location matches that of the EPB that imposed the sanction. We define a firm as a state-owned enterprise (SOE) if *tianyancha.com* labels it as state-owned and as a privately owned enterprise (POE) otherwise.[18]

2.4 Green initiatives

We use the number of green patents as a measure of firms' green initiatives. Chinese patent records are sourced from the Chinese National Intellectual Property Administration and are labeled as "green" according to the International Patent Classification (IPC) Green Inventory. We focus on the number of green patent applications at the firm level.

[18] SOEs in China are defined as having either full or majority ownership by state institutions or significant control through ownership stakes held by local, regional, or central government entities. Chinese business data platforms, such as *Tianyancha* and *Qichacha,* track these ownership structures and classify companies accordingly to help users distinguish between state-owned, privately owned, and foreign-invested entities.

One might propose that a more straightforward measure of a firm's conservation efforts would be its emission data. However, to the best of our knowledge, the commonly used plant-level emissions database, the Environmental Survey and Reporting (ESR) database released by the Ministry of Ecology and Environment (formerly the Ministry of Environmental Protection), is only available until 2014, while many of the EPB reforms occurred after 2014. Listed firms report emissions data, but local emissions may be more accurately captured at the plant level, and most emissions come from unlisted firms. In the appendix, we examine city-level emissions data from various sources. Additional details are discussed in Section 4.3.

2.5 Control variables

First, we collect city-year level socioeconomic covariates that might affect biodiversity and firm activities from City Statistic Yearbooks. These yearbooks provide a wide range of statistical data compiled by national or local statistical agencies, including economic indicators, population statistics, social development metrics, environmental data, infrastructure details, and other relevant data points that offer insights into the development and performance of Chinese cities. Basic controls in our analysis include population density (population scaled by land area), urbanization rate (the proportion of a city's population residing in urban areas), the logarithm of GDP, industrial structure (the fraction of primary and second industry output over GDP), real estate investment to GDP ratio (China's most significant industry over recent decades), and green space ratio (the percentage of green land over total land area).

To account for climate variables that may influence bird diversity, birdwatching activity, and pollution levels, we incorporated average temperature (°C), precipitation (mm), and wind speed (m/s) into our analysis. These variables are calculated by averaging monthly latitude-longitude grid data sourced from the ERA5-Land dataset, a high-resolution global reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) (Munoz Sabater 2019).

Finally, we consider birdwatching efforts and observer abilities that may influence birdwatching outcomes. For the city-year level analyses, we control for the total number of birdwatching events and the total hours spent observing (effort hours). At the birdwatching event level analyses, we control for effort hours and unique birdwatching account ID fixed effects. The latter captures observer ability. These data are directly obtained from eBird and birdreport.

Detailed variable definitions for all above-mentioned variables are presented in Appendix Table A1.

3. EPB Reform and Bird Diversity

3.1 Baseline results

Our baseline analyses examine the impact of Chinese EPB reforms on bird species diversity. The reforms were implemented staggeredly across Chinese cities, which creates a natural setting for a Difference-in-Differences (DiD) analysis. The baseline Two-Way Fixed Effects (TWFE) regression model is specified as follow:

$$Birds\ species_{i,t} = \alpha + \beta \times PostReform_{i,t} + \gamma \times X_{i,t} + city_i + year_t + \varepsilon_{i,t} \quad (1)$$

where the dependent variable, *Bird species*$_{i,t}$, represents the total number of unique bird species observed in city i in a year t. The independent variable of primary interest, $PostReform_{i,t}$, is a dummy variable that equals one if city i has experienced EPB vertical management reform on or after year t. The coefficient β of the $PostReform_{i,t}$ captures the DiD effects of EPB reform on bird diversity. $X_{i,t}$ is a vector of city-year controls, including city population density, urbanization rate, city GDP (log), industrial structure, real estate investment to GDP ratio, green space ratio, temperature, precipitation, and wind speed. In addition, we control for covariates of birdwatching activities, including the number of birdwatching events and the total effort hours spent. The city fixed effects ($city_i$) and the year fixed effects ($year_t$) are included to absorb all time-invariant city effects on bird diversity and all annual shocks common to all cities, respectively. The regression is clustered at the city level.

We also perform a similar DiD regression at the event level. The dependent variable, *Birds observation rate*, measures bird abundance and is defined as the average number of birds observed per hour in each birdwatching event. In this model, we include both city-level controls and event-level controls to account for relevant covariates. The event-level analysis, in particular, allows us to further include the unique birdwatching account ID (observer ID) to control for observer ability.

Upon the implementation of the reform, the local EPBs are expected to enforce regulations more stringently. This stricter enforcement is expected to reduce pollution and consequently improve biodiversity. Consistent with our hypothesis, the empirical results in Table 2 indicate that cities experience a significant increase in bird diversity after reform.

[Table 2 about here]

Specifically, columns 1–3 show that post-reform cities had an average increase of 16.1–23.8 additional bird species, representing a 21.8%–32.3% increase when evaluated at the sample mean (73.7). Columns 4–7 suggest that, on average, 22.3–29.4 more birds were observed in each birdwatching event in post-reform cities, representing a 35.0%–46.1% increase relative to the sample mean (63.8). Column 7, which includes the birdwatching account ID to control for observer ability, reveals that even for the same observer, 27.0 more birds were observed per hour post-reform.[19] These findings provide robust evidence that EPB reform has had a positive and significant impact on avian biodiversity in the treated cities.[20]

Interpreting these results from a different vantage point, the estimates underscore the substantial negative effects of past human activities on biodiversity, suggesting that at least 21.8%–32.3% of the bird species have been adversely affected by local governments prioritizing economic development and weakly enforcing environmental laws. Furthermore, these results represent only a lower-bound estimate of the costs to biodiversity by lax enforcement. As we discuss in Section 4, the reform has not entirely eliminated violations of pollution regulations by state-owned-enterprises (SOEs).

Next, we employ a dynamic DiD method to assess the parallel trends assumption. Recent studies have shown that traditional TWFE models can produce biased dynamic estimates in staggered DiD contexts given the presence of heterogeneous treatment effects (e.g. Baker, Larcker and Wang 2022). To address this issue, we adopt the method of Sun and Abraham (2021), which proposes

[19] In Appendix Table A2, we replicate Table 2 using only eBird events, allowing us to include effort distance and number of observers per event as additional controls, further accounting for birdwatching effort and ability. The results remain robust.
[20] To account for potential spatial correlation among residuals, we adjust standard errors using the method proposed by Colella et al. (2019). We define spatial correlation within a 219-kilometer radius, approximately three times the average city radius of 73 kilometers (calculated by assuming each city is a circle and using its land area).

‘‘interaction-weighted’’ estimators for estimating dynamic treatment effects; we leave the original dynamic TWFE analyses in Appendix Figure A1 for reference. [21]

Figure 5 illustrates the parallel trends analysis by plotting the coefficients from a dynamic Sun and Abraham (2021) model. As observed, both bird species diversity and abundance show an immediate and significant increase post-reform, indicating an immediate positive effect of the EPB reforms on avian biodiversity.

[Figure 5 about here]

3.2 Robustness and placebo analyses

First, we conduct a robustness analysis using an alternative sample period between 2014 and 2019. Since 2014, birdwatching records increased significantly, likely due to the growing popularity of birdwatching in China and the launch of birdreport.cn online in 2014. Additionally, the majority of cities (216 of 277) underwent EBP reforms between 2014 and 2019. As shown in Appendix Table A3, the estimated effects of EBP reform on bird diversity and bird observation rate remain robust during this short window.

We next investigate whether biodiversity in a city is influenced by reforms in neighboring cities. This investigation helps isolate the impact of such reforms, accounting for potential spatial spillover effects in ecological systems. As reported in Table A4, the coefficient of *Post reform* is positive and significant across all columns, consistent with the main results in Table 2. However, the coefficient of *Post neighbor reform* is mixed: in Panel A, there are no significant results, while in Panel B, the coefficient is not consistently significant across columns. Taken together, our analysis suggests that reforms in adjacent cities did not exert a strong or statistically significant positive effect on local biodiversity. Specifically, reforms in neighboring cities had no impact on bird species richness and only a marginal effect on bird abundance. These results demonstrate that local reforms play a far more critical role than neighboring reforms in enhancing both bird species diversity and abundance.

[21] Sun and Abraham (2021)’s method employs a weighted estimator that interacts treatment timing with time fixed effects, enabling the calculation of average treatment effects for each period post-treatment. This approach reduces bias by avoiding the use of already-treated units as controls.

The findings in Table A4 carry two implications. First, they provide empirical evidence that the effectiveness of environmental policy reform is geographically contained, reinforcing the importance of local governance in ecosystem management. Second, the fact that avian populations respond predominantly to immediate habitat conditions—rather than broader regional policy trends—further strengthens causal attribution. By disentangling the influence of neighboring policies, we demonstrate that observed biodiversity changes are plausibly caused by local interventions, not confounding spatial spillovers.

To strengthen our causal inference, we conduct a third set of robustness tests examining the heterogeneous effects of EPB reforms. Specifically, we contrast reform impacts on breeding sites versus stopover sites for migratory birds. Migratory birds often exhibit lower breeding site fidelity, especially in polygamous species and among males, allowing them to adjust their stopovers in response to environmental changes. In contrast, breeding sites are typically more fixed, as many bird species show high site fidelity for nesting. Consequently, cities on migration routes are more likely to observe immediate changes in bird diversity in response to EPB reforms.

We identify breeding and migration areas in China from the *National Action Plan for the Protection of Bird Migration Routes, 2021–2035* (Appendix Table A2 in National Forestry and Grassland Administration 2022) and perform the baseline regressions on sub-samples of migration and breeding cities. Appendix Figure A2 draws the spatial distribution of these cities, and the regression results (Panel A of Appendix Table A5) show that EPB reforms fostered bird diversity only in migration cities.[22]

In the same vein, we compare EPB reform effects on migratory versus resident birds, assuming that local reforms are more likely to benefit migratory species. We classify bird species as migratory or resident based on the *List of Migratory Birds in China* (Appendix Table A1 in National Forestry and Grassland Administration 2022). As shown in Panel B of Appendix Table A5, migratory bird diversity increases significantly post-reform, while the effect on resident birds is minimal.

[22] We acknowledge that the sample sizes for each city type are unbalanced, and these findings provide only supportive evidence for robustness.

3.3 Environmental penalties

This section explores the mechanisms through which the EPB reform benefits biodiversity. We use the environmental penalties imposed by EPBs on corporations as a proxy for enforcement strength. Although penalties alone can be an ambiguous indicator—low penalty counts might signify either weak enforcement or genuinely good environmental quality—the DiD framework addresses this ambiguity by controlling for city and year fixed effects, enabling a robust comparison of enforcement outcomes before and after the reform.

We utilize comprehensive records of environmental penalties in China available from 2003 and construct two measures for each city-year: the total number of penalty cases imposed and the total fine amount (in million yuan). To account for significant inflation in China over recent decades and to ensure that increased fines post-reform are not merely a result of inflation, we also deflate the fine amounts to the base year of 2003.

[Table 3 about here]

We employ the same DiD regression model as in equation (1) except for altering the dependent variables. The results are reported in Table 3. The results indicate that local EPBs enforced environmental laws more strictly after the reform, resulting in a 153.5% increase in the number of penalties and a 144.7% increase in total fine amounts when evaluated at the mean. Even after adjusting for inflation, the increase in fines reaches 142.7%. The economic magnitude of these findings is substantial. Figure 6 presents the results of the Sun and Abraham (2021) dynamic DiD analysis on penalties. As shown, the coefficients remain close to zero prior to the reform but increase sharply immediately afterward. The effects are particularly pronounced from years 0 to 2, indicating that officials responded strongly to the reform by enforcing penalties more rigorously once EPBs gained independence. This pattern suggests a direct link to the policy change rather than a gradual shift in environmental conditions or corporate behavior. Alternative dynamic DiD analyses using the traditional TWFE method are presented in Appendix Figure A3.

[Figure 6 about here]

To quantitatively assess the effectiveness of environmental enforcement on avian diversity, we combine the bird species and environmental penalty results. On average, the total fine amount increased by 7.1 million yuan (column 4 of Table 3), while the number of bird species increased by 23.8 (column 2 of Table 2), conditional on the same set of control variables. This implies that for every additional 1 million yuan in penalties imposed, approximately 3.4 bird species are preserved. This finding highlights the responsiveness of ecological systems to human actions and the effectiveness of strict conservation initiatives.

3.4 Enforcement stringency, pollution types, and bird diversity

To verify that improved biodiversity is indeed driven by stricter enforcement of environmental laws following the EPB reforms, we conduct a subsample analysis based on the observed intensity of changes in enforcement.[23] Specifically, we measure enforcement stringency by the increase in penalties, defined as the difference in the number of penalties between the year of reform (year 0) and two years pre-reform (year -2). Using this metric, we categorize cities into two groups: "stricter" cities, where the increase in penalties from pre- to post-reform is above the median, and "looser" cities, where the increase in penalties is below the median. For each subsample, we examine the effects of EPB reform on bird species richness and bird observation rates using the specifications from columns 3 and 6 of Table 2. The results are presented in Table 4. As shown, improvement in avian diversity concentrates in cities that have stricter regulation enforcement post-reform.

[Table 4 about here]

The granularity of the environmental penalty data also enables a deeper understanding of how different types of pollutants affect biodiversity. The Environmental Protection Administrative Penalties dataset provides detailed reasons for each penalty issued, with most cases falling into four pollution categories: air, water, solid waste, and industrial noise. Following the approach in Table 4, we categorize cities into stricter and looser enforcement groups based on penalty increases within each pollutant category and examine the effects of the reform on bird diversity.

[23] The variation in enforcement intensity across cities can have complex underlying reasons. As this is not within the scope of our study, we focus solely on the observed changes in enforcement intensity.

[Table 5 about here]

The results, presented in Table 5, indicate that in addition to air and water pollution,[24] solid waste plays a critical role in biodiversity outcomes. These findings underscore the importance of considering a broader range of pollutants when researching biodiversity and sustainable finance-related topics. Each type of pollution carries significant environmental consequences, and policymakers, firms, and investors should account for the impact of multiple pollutants beyond air and water when assessing environmental risks and sustainability practices.

4. Local and Central Protectionism

In this section, we investigate which types of firms face increased penalties following the reform. This question is crucial because the EPB reforms likely created a new regulatory landscape for firms by increasing the potential of high-cost penalties. This heightened penalty risk could significantly impact firms' financial performance and behavior and, consequently, have implications for market assessment of firms' financial risks.

This question can also be framed from another angle: Which types of firms may have previously benefited from regulatory leniency and, consequently, contributed to biodiversity degradation? By pinpointing the firms most impacted by heightened enforcement, we gain a clearer view of how administrative independence drives accountability and how it may affect achieving biodiversity conservation goals by increasing regulatory enforcement stringency.

As introduced in Section 2.2, the EPB vertical management reform fundamentally aims to enhance administrative independence by reducing local government control. Drawing on the literature on judicial and administrative independence (e.g., Liu et al. 2022), we analyze the effects of the EPB reforms through the lens of protectionism, including both local and central protectionism.

[24] Existing research has primarily focused on air and water pollution (e.g., Greenstone and Hanna 2014, Dasgupta et al. 2023).

4.1 Local protectionism

Local protectionism refers to the practice by which local governments favor businesses within their jurisdiction to stimulate economic growth, often resulting in leniency in regulatory enforcement of other sectors. This form of protectionism can arise because local governments rely on local firms for tax revenue, employment, and overall economic stability. As a result, local protectionism can undermine broader regulatory objectives, including environmental protection, by allowing firms to operate with reduced oversight. Local protectionism is evident in China. For instance, Liu et al. (2022) found that local courts favor local firms, which have higher win rates under conditions of judicial imperfection. In the environmental sector, Bai et al. (2021) reveal that city-level restrictions on used vehicle emissions did not significantly improve air quality and may have actually hindered market development and social welfare. This work highlights how local governments may engage in local protectionism under the pretense of environmental protection.

Within our context, local governments exercised leniency in enforcing environmental regulations prior to the EPB reforms, especially for local firms that significantly contributed to local tax revenue and were more likely to be politically connected to local government through various local networks. The reform aimed to increase the EPBs' administrative independence and reduce local protectionism, resulting in increased environmental penalties for these previously "protected" local enterprises. Therefore, we hypothesize that local firms are the major targets for paying increased fines.

In Table 6, we replicate the analysis from Table 3 but divide the sample of sanctioned firms into local versus non-local firms. We identify a firm as local if its registration county is identical to the EPB county.[25] The results indicate that, post-reform, penalties were predominantly imposed on local firms. Neither the number of penalties nor the total fine amount imposed on non-local firms increased significantly after the reform.

[Table 6 about here]

[25] We identified the firms' registration locations for 68.79% of the penalty records. Among these identified cases, 84.22% of penalties were directed at local firms, while 15.78% were issued to non-local firms.

4.2 Central protectionism

Central protectionism occurs when firms with direct ties to the central government receive favorable treatment regardless of their geographical location. This protection can stem from the firm's political connections, strategic importance, or contribution to national economic objectives, often leading to selective enforcement of regulations. Central protectionism can limit the effectiveness of local and regional regulatory efforts by providing exemptions or reduced scrutiny to certain powerful firms. This problem is particularly severe in China's environmental sector (Wang et al. 2003, Hering and Poncet 2014, Eaton and Kostka 2017, Zhao, Jia and Zhang 2023). Centrally connected firms are typically state-owned enterprises (SOEs). As Eaton and Kostka (2017) document, Chinese SOEs receive substantial exemptions from environmental regulations yet were responsible for over 60% of reported environmental violations, a figure derived from compiled news reports across multiple media sources. In contrast, our environmental penalty database indicates a significant regulatory privilege: only 4.21% of penalty records were issued to SOEs.

We posit that SOEs are less likely to experience a significant increase in environmental penalties or associated costs following the EPB reforms, potentially due to their continued strong political link to the central government. In Table 7, we replicate the analysis from Table 3 but divide the sample into SOEs and privately owned enterprises (POEs). The results indicate that, post-reform, increased penalties are predominantly imposed on POEs.

[Table 7 about here]

In Appendix Figures A4 and A5, we plot the Sun and Abraham (2021) dynamic DiD coefficients for local versus non-local firms (Figure A4) and SOEs versus POEs (Figure A5). The sharp increase in penalties post-reform is clearly concentrated among local and privately owned firms.

4.3 Firms' green initiatives

Our final test investigates how corporations respond to the EPB reforms. Firms typically make decisions based on cost-benefit analyses. Facing an increased likelihood of potentially high-cost penalties, firms can either reduce pollution by decreasing output or invest in green initiatives that curb pollution in the long term while maintaining output levels. While these approaches are not mutually exclusive, existing research in China suggests a stronger inclination toward investing in green initiatives. For instance, Liu et al. (2021) find that firms reduced emissions by upgrading production technology after China's Key Cities for Air Pollution Control policy. Additionally, Huang and Lei (2021) document that firms, particularly non-state-owned enterprises, make green investments in response to environmental regulations.

Data limitations make it difficult to document whether firms actually reduce pollution following the EPB reforms. The commonly used plant-level emissions database, the Environmental Survey and Reporting (ESR) database, is only available until 2014, and many of the EPB reforms took place after this period. Furthermore, although listed firms report emissions data, local emissions are often more accurately captured at the plant or small unlisted firm level. To remedy these data limitations, we collect city-level emissions data from various sources, assuming that city-level pollution is highly correlated with emissions from firms engaged in local production activities. The results are reported in Appendix Tables A6 and A7. We begin by assessing air quality improvements associated with the reform (Appendix Table A6). Using Air Quality Index (AQI) data, we find that the reform is associated with lower AQI, lower PM2.5, and lower PM10. Additionally, the reform correlates with fewer pollution days per year. We also examine aggregate city emissions data reported by city yearbooks (Appendix Table A7) and find that wastewater, SO_2, and soot levels all decreased, particularly after 2014, when the majority of the reforms were implemented.

The next question is whether the reduced emissions were driven by firms' reduced production in response to more stringent environmental enforcement. Since we again lack firm-level production or output data, especially for local unlisted firms, we rely on city-level proxies, in particular GDP, to approximate output. Our analysis (Appendix Table A8) shows that overall city-level output did not decrease following the reform, suggesting that the reform did not negatively impact economic activities at the city level.[26]

[26] We acknowledge that our findings, specifically that GDP remains unaffected, may align well with the EPB reform but may not necessarily apply to other policies aimed at reducing pollution in China. Chen, Li and Lu (2018) found that when local officials' performance evaluations were adjusted in 2005 to emphasize environmental targets, GDP growth slowed due to officials' career-related incentives. We argue that officials may prioritize environmental improvements, even at the expense of

While the city-level results indicate that pollution levels decreased without negatively impacting output post-reform, we examine whether firms reduced emissions by investing in green initiatives. We use green patents as a measure since patent data is available for all firms, including unlisted entities, whereas other investment metrics are generally accessible only for listed firms. Using the number of green patent applications as the dependent variable, we find significant increases in green patents among local firms[27]—particularly local privately owned firms—following the EPB reforms (Table 8). In contrast, SOEs do not show an increase in green patent investments.

[Table 8 about here]

The results are consistent with previous findings on protectionism, showing that only local privately owned firms face an increased penalty risk. In contrast, SOEs continue to benefit from central protectionism and leniency in enforcement, which reduces their incentive to invest in green initiatives. By examining the heterogeneous effects of environmental reform, we clarify the new costs imposed on different types of firms, with implications for financial assessments. Additionally, this analysis highlights the challenges of implementing conservation policies in politically connected, growth-oriented landscapes.

5. Conclusion

This research provides evidence that strengthening the enforcement of environmental regulations enhances biodiversity. We leverage birdwatching data to obtain a sensitive measure of avian diversity and utilize the staggered implementation of China's Environmental Protection Bureaus (EPB) reform as an exogenous variation in environmental policy enforcement stringency. Following the reform, both bird species richness and abundance increases significantly, with a substantial effect size. Improved enforcement stringency is demonstrated by increased fines imposed on firms and biodiversity

economic output, when such targets are set as key performance indicators. However, the EPB reform emphasizes the administrative independence of environmental departments, which should have a comparatively lower impact on economic growth.

[27] Data on green patents for non-local firms is unavailable due to difficulties in tracking firms' activities across different cities.

gains concentrated in cities where enforcement strengthened more than the median change observed after the reform.

The EPB reforms expanded the administrative independence of environmental departments, alleviating local protectionism. We find that penalties increased notably for local rather than non-local firms, underscoring the effectiveness of the EPB reforms and the importance of administrative and judicial independence under the rule of law. However, state-owned enterprises (SOEs) remain shielded from regulatory scrutiny due to central protectionism. Additionally, we find that after the reform, pollution levels decreased without adversely affecting economic output, and privately owned firms demonstrated increased green innovation, while SOEs did not.

Overall, our findings reveal how administrative independence in environmental governance can mitigate biodiversity loss while highlighting the ongoing regulatory gap for SOEs. In contribution to the literature on biodiversity conservation and sustainable finance, this study demonstrates that effective enforcement of environmental regulations can foster corporate compliance and ecological benefits. Achieving equitable environmental accountability across all firm types, however, will require further reforms to address central protectionism. This work advocates for policies designed to balance economic goals with sustainability, ensuring biodiversity conservation alongside industrial growth.

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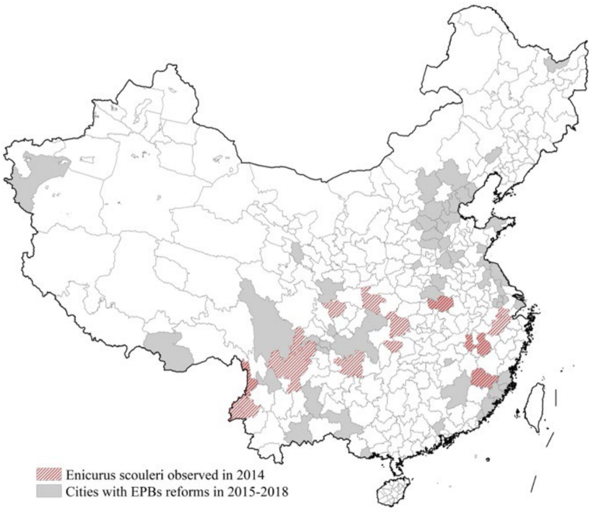
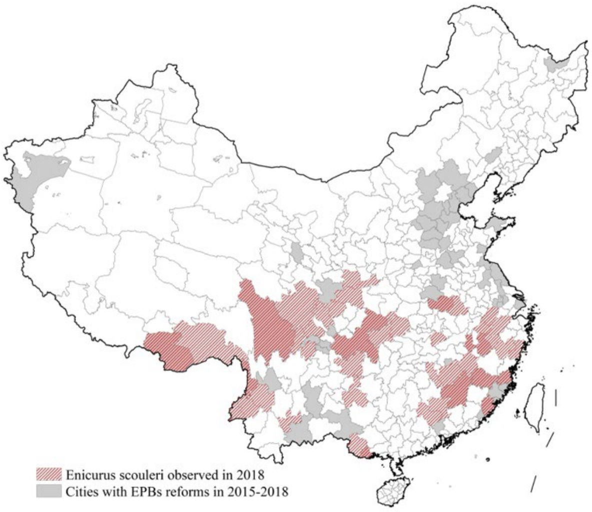
Panel A. Little Forktail (*Enicurus scouleri*)



Panel B. Cities with Little Forktails observed in 2014



Panel C. Cities with Little Forktails observed in 2018

Figure 1. The expansion of Little Forktail (*Enicurus scouleri*) before and after reform.

Notes: This figure illustrates the spatial distribution of the Little Forktail (Enicurus scouleri). Panel A features an image of the specie, sourced from https://ebird.org/species/litfor1/IN-UL-PI. In Panel B, shaded areas represent cities where the Little Forktail was observed in 2014, while gray areas indicate cities that underwent EBP reform between 2015 and 2018. Panel C shows cities with Little Forktail observations in 2018.

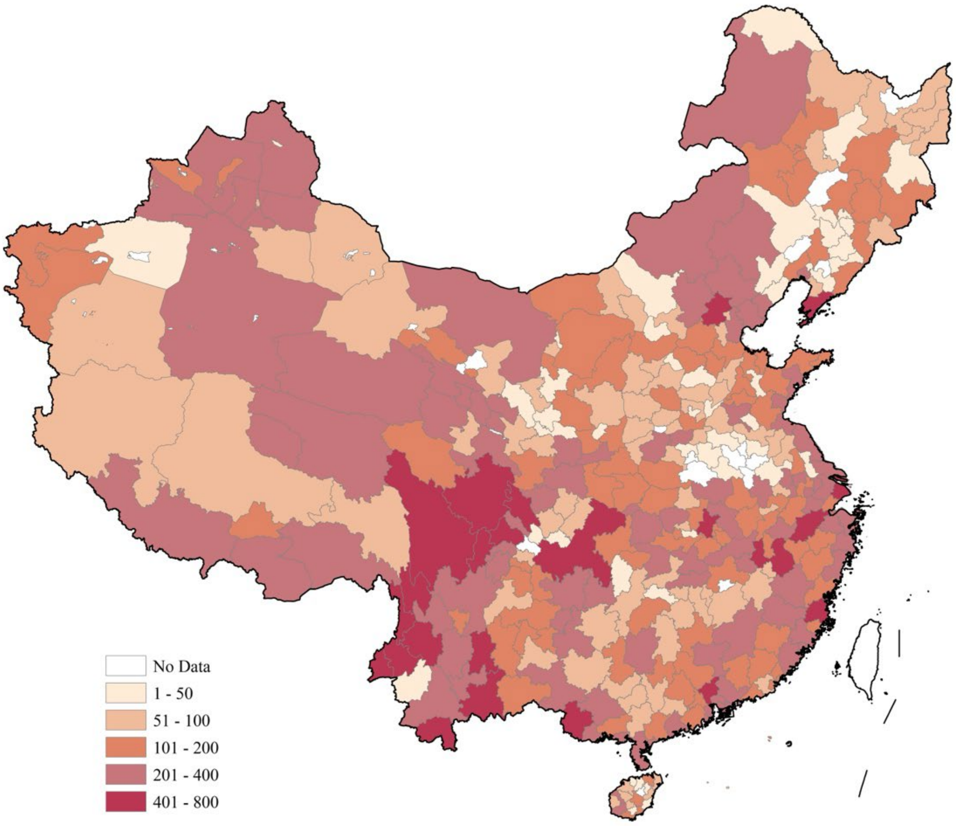


Figure 2. Number of bird species, 2003–2019.

Notes: This figure illustrates the spatial distribution of bird species richness across Chinese cities based on the total number of unique bird species observed from 2003 to 2019. The data is derived from birdwatching records sourced from *eBird.com* and *birdreport.cn*. During the sample period, a total of 1,586 bird species were recorded across China.

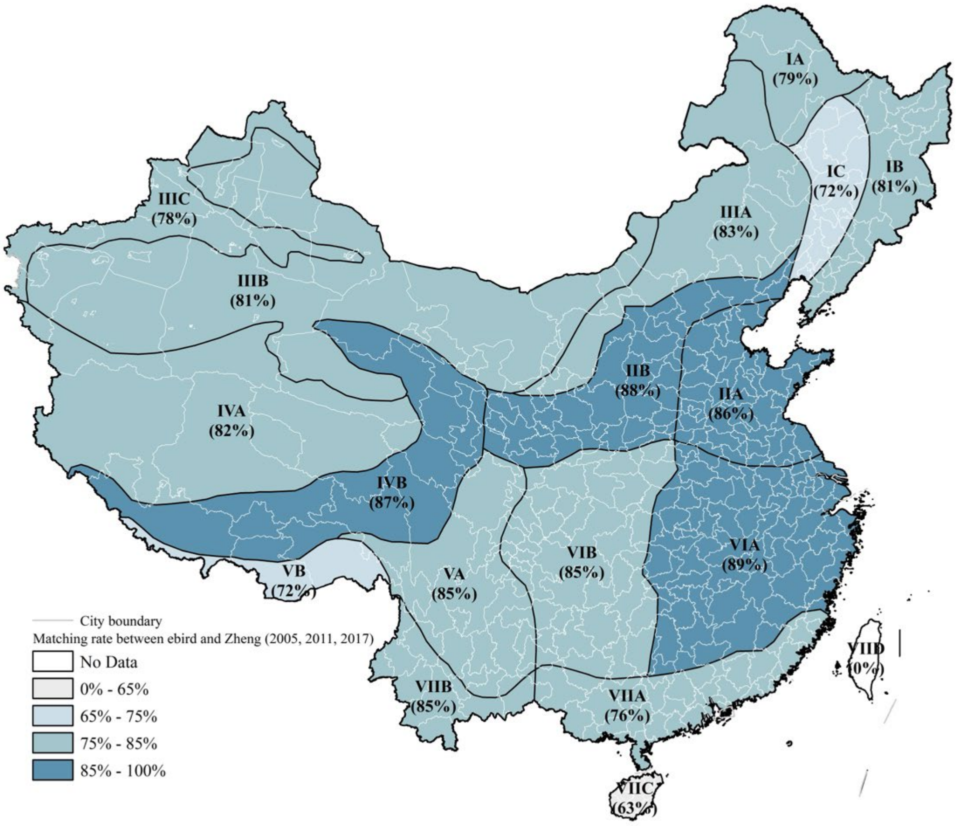


Figure 3. Cross verification of bird distributions in zoogeographical regions.

Notes: This figure illustrates the concordance between bird species distributions derived from birdwatching data and those documented in Zheng's monographs (Zheng 2005, Zheng 2011, Zheng 2017). These monographs provide comprehensive lists of bird species and their occurrences across China's zoogeographical regions. For an in-depth explanation of these regions and access to the dataset from Zheng's works, please refer to Zhang et al. (2022). To assess the matching rate, we compiled two datasets for each zoogeographical region: 1) the complete list of bird species from Zheng's monographs, and 2) the list of species observed by *eBird.com* and *birdreport.cn* users. We then calculated the percentage of species in Zheng's list that were also reported by bird watchers. In the figure, these matching rates are presented in parentheses and are visualized by varying shades of blue, with darker hues indicating higher rates of concordance.

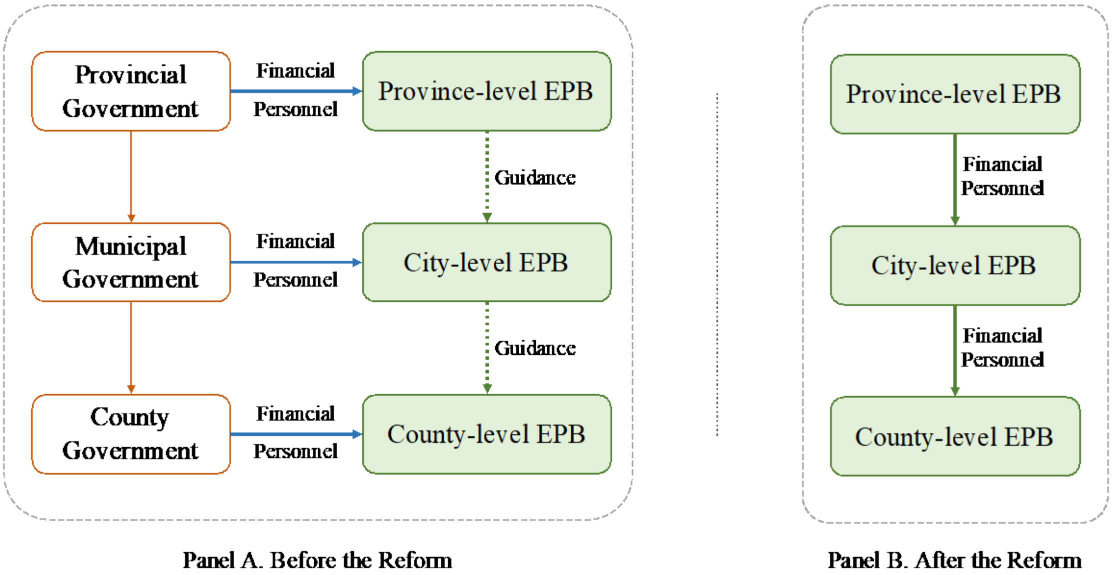
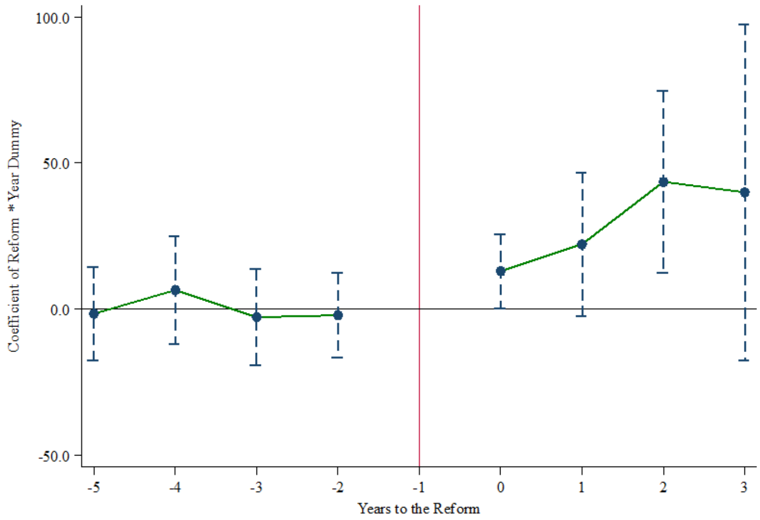
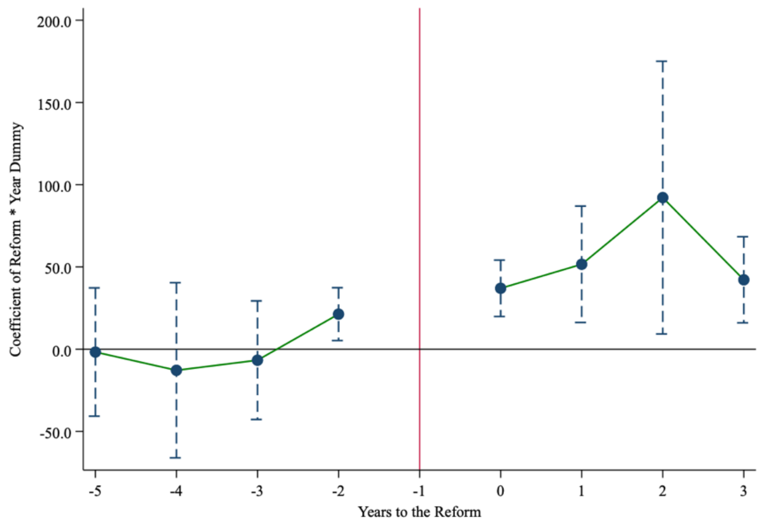


Figure 4. Schematic diagram of EPB reforms.

Notes: The figure illustrates the environmental system pre- and post-reform of a hypothetical Chinese city that supervises one county. In China, on average, each city has jurisdiction over 10 counties. Panel A depicts the system before the reform. In this pre-reform system, the county-level EPB was controlled by the county government while only nominally subordinated to the city-level EPB and receiving regulatory guidance from it. Panel B depicts the system after reform. The restructuring involved the city-level EPB assuming responsibility for the funding, staffing, and overall management of the county-level EPB.



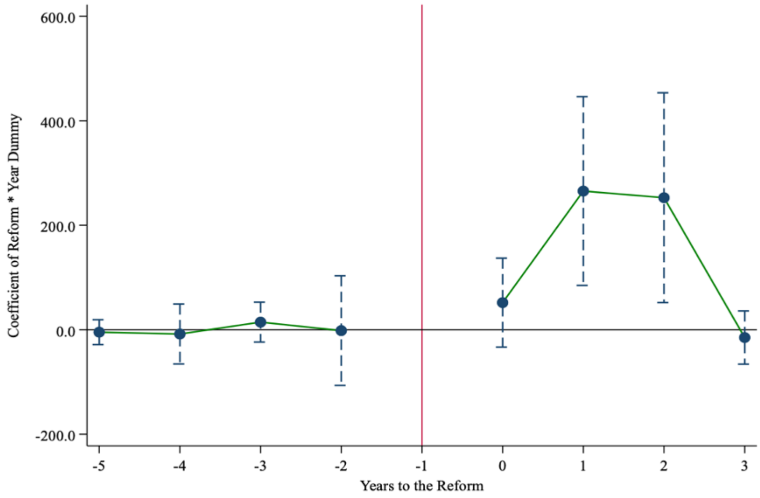
Panel A. Bird species



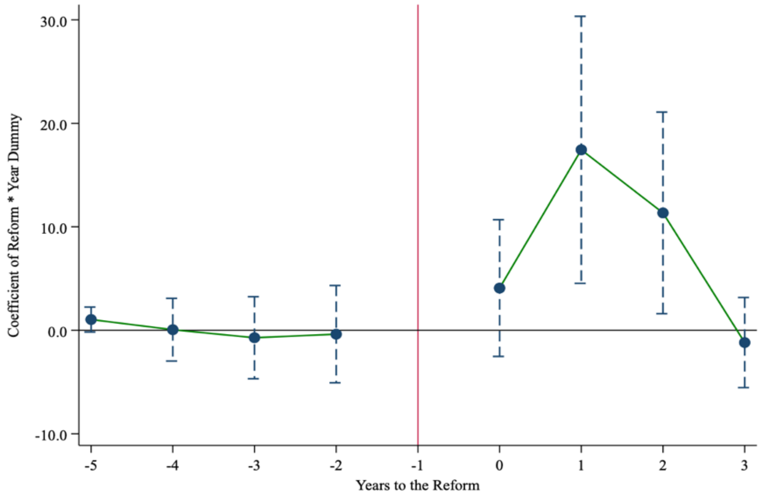
Panel B. Bird observation rate

Figure 5. Parallel trends: the effects of EPB reforms on bird diversity.

Note: This figure illustrates the pre- and post-trends in the effect of EPB reforms on bird diversity. The coefficients (with 95% confidence intervals) are derived from regressing the bird species (Panel A) and bird observation rate (Panel B) on relative-to-reform year dummies for the period between 2003 and 2019, using the Sun and Abraham (2021) method. In the figures, "year -1," or the year immediately preceding the reform, is set as the reference year. "year-5" indicates five years or more prior to the reform, and "year 3" signifies three or more years after the reform. The regressions include city-level and birdwatching event controls (see Table 2), as well as city and year fixed effects.



Panel A. Number of penalties



Panel B. Fine amount

Figure 6. Parallel trends: the effects of EPB reforms on penalties.

Notes: This figure shows the pre- and post-trends in the effect of EPB reforms on penalties. The coefficients (with 95% confidence intervals) are obtained from regressing the number of penalties (Panel A) and the total fine amount in million yuan (Panel B) on relative-to-reform year dummies for the period between 2003 and 2019, using the Sun and Abraham (2021) method. In the figures, "year -1," or the year immediately preceding the reform, is set as the reference year. "year-5" indicates five years or more prior to the reform, and "year 3" signifies three or more years after the reform. The regressions include city-level controls (see Table 2), as well as city and year fixed effects.

Table 1. Summary statistics.

	Obs.	Mean	S.D.	Min	Max
Independent variables, 2003-2019					
Post Reform (dummy)	4,709	0.12	0.32	0.00	1.00
Birdwatching at city-year level, 2003-2019					
Bird species	1,519	73.65	76.85	1.00	530.00
Total # birdwatching events	1,519	25.17	105.40	1.00	2273.00
Total effort hours	1,519	93.27	379.50	1.00	7970.00
Birdwatching at event level, 2003-2019					
Bird observation rate (# birds observed per hour)	40,541	63.80	173.10	0.09	10,026.00
Effort hours per event	40,541	3.65	2.34	1.00	12.00
Enforcement at city-year level, 2003-2019					
Number of penalties	4,709	84.10	322.60	0.00	7,382.00
Fine amount (in million yuan)	4,709	4.93	17.58	0.00	259.00
Fine amount (in million yuan, deflate to 2003)	4,709	3.35	11.83	0.00	169.60
City-year controls, 2003-2019					
Population density (in 1,000 persons/sq.km)	4,625	0.95	0.94	0.02	14.05
Urbanization rate (%)	4,562	48.81	17.24	11.17	100.00
GDP (in billion yuan)	4,614	108.70	260.50	0.98	3816.00
Primary industry output (scaled by GDP, %)	4,613	7.03	6.71	0.03	44.88
Secondary industry output (scaled by GDP, %)	4,613	48.74	12.38	11.04	90.97
Real estate investment (scaled by GDP, %))	4,486	14.15	9.75	0.00	123.40
Green space ratio (%)	4,574	3.82	5.39	0.00	59.69
Temperature (°C)	4,709	13.95	5.25	-3.70	25.72
Precipitation (mm)	4,709	3.08	1.49	0.25	7.76
Wind speed (m/s)	4,709	1.02	0.37	0.35	3.02
Pollution at city-year level					
Air quality, 2014-2019					
AQI (ug/m3)	1,533	75.68	21.73	31.18	178.10
PM2.5 (ug/m3)	1,533	46.12	17.07	9.09	129.80
PM10 (ug/m3)	1,533	81.00	30.06	24.20	234.00
Number of slight pollution days	1,533	67.28	54.57	0.00	285.00
Number of median pollution days	1,533	21.90	24.80	0.00	183.00
Number of heavy pollution days	1,533	8.80	12.77	0.00	129.00
Number of severe pollution days	1,533	1.61	3.61	0.00	41.00
Pollutants, 2003-2019					
Wastewater (in million tons)	4,447	70.61	91.75	0.01	868.00
SO2 (in 1,000 tons)	4,447	52.13	57.83	0.00	683.20
Soot (in 1,000 tons)	4,440	26.95	34.93	0.01	787.50
NOx (in 1,000 tons),	680	17.64	15.52	0.09	92.90
Green patent at city-year level, 2003-2019					
Number of green patents applied	4,709	206.50	386.90	1.00	1528.00
Number of green patents applied, POE	4,709	4.54	9.81	0.00	38.00
Number of green patents applied, SOE	4,709	115.60	232.80	0.00	933.00

Refer to Appendix Table A1 for detailed definition of the variables.

Table 2. Effects of EPB reforms on bird diversity.

This table examines the impact of Environmental Protection Bureau (EPB) reforms on bird diversity. We utilize two dependent variables to measure bird diversity. In columns 1–3, *bird species* refers to the total number of unique bird species observed in a city-year, with regressions at city-year level. In columns 4–7, *bird observation rate* is defined as the average number of birds observed per hour in each birdwatching event, with regressions at the event level. The key explanatory variable, *post reform*, is an indicator equal to one if the city has experienced EPB reform on or after year *t*. Control variables are added progressively throughout the analysis. City-level controls include population density, urbanization rate, GDP (log), industrial structure, the real estate investment-to-GDP ratio, green space ratio, average temperature, precipitation, and wind speed. We also control for available birdwatching covariates, including the number of birdwatching events and total observation hours. All regressions include city and year fixed effects. Column 7 further includes birdwatching account fixed effects. The full sample comprises approximately 40,000 birdwatching records from 277 cities in China between 2003 and 2019. City-years without any birdwatching activities are omitted in the regression. Standard errors clustered at the city level are reported in parentheses. Standard errors adjusted for arbitrary clustering to account for spatial correlation are reported in brackets (Colella 2019). *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	Bird species (at city-year level)			Bird observation rate (at event level)			
	1	2	3	4	5	6	7
Post reform	16.097**	23.812***	16.563**	22.281*	29.423**	29.046**	27.013**
(SE)	(7.397)	(7.576)	(6.548)	(11.871)	(13.965)	(13.915)	(10.639)
[Colella SE]	[7.861]	[8.088]	[7.122]	[12.233]	[14.481]	[14.438]	[10.455]
Population density		-0.882	0.650		-15.374	-15.317	-15.295*
		(6.797)	(5.502)		(11.726)	(11.511)	(8.444)
Urbanization rate		-1.444	-0.467		0.366	0.305	-0.315
		(0.921)	(0.657)		(0.885)	(0.860)	(0.735)
GDP (log)		39.049***	34.448***		-23.881	-23.379	-12.080
		(14.448)	(12.295)		(33.542)	(32.931)	(25.597)
Primary ind. output/GDP		0.928	0.428		-9.786	-9.651	-9.456
		(2.232)	(1.822)		(7.901)	(7.897)	(8.058)
Secondary ind. output/GDP		-0.505	-0.413		0.367	0.358	-1.192
		(0.502)	(0.427)		(1.863)	(1.853)	(1.420)
Real-estate investment/GDP		-0.331	-0.089		-0.321	-0.318	-0.499
		(0.339)	(0.253)		(0.866)	(0.857)	(0.422)
Green space ratio		1.097	0.521		-0.546	-0.458	-0.479
		(1.225)	(0.733)		(1.611)	(1.593)	(1.492)
Temperature		0.231	0.230		-21.195*	-21.411*	-21.714*
		(4.861)	(4.265)		(11.959)	(11.967)	(12.143)
Precipitation		-0.828	-1.510		3.953	4.174	3.697
		(2.499)	(2.113)		(5.793)	(5.779)	(4.418)
Wind speed		-7.789	-10.123		1.998	0.402	-19.486
		(15.001)	(14.007)		(33.501)	(33.063)	(20.380)
Total # birdwatching events			-0.141				
			(0.427)				
Total effort hours			0.109				
			(0.109)				
Effort hours of the event						-2.118**	-0.459
						(0.929)	(1.102)
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birdwatching account FE							Yes
R-squared	0.698	0.710	0.776	0.240	0.243	0.244	0.344
Observations	1,504	1,357	1,357	40,534	35,470	35,470	34,690

Table 3. Environmental penalties.

This table explores the impact of Environmental Protection Bureau (EPBs) reforms on environmental penalties conducted by local EPBs. We utilize three dependent variables to measure environmental penalties: the number of penalties, the total fine amount (in million yuan), and the total fine amount deflated to the year 2003 (in million yuan). The key explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year *t*. Control variables are identical to column 2 of Table 2. All regressions include city and year fixed effects. The analysis encompasses 277 cities from 2003 to 2019 in China. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	Number of penalties		Total fine amount		Total fine amount (deflated)	
	1	2	3	4	5	6
Post reform	160.318***	129.092**	7.773**	7.134**	5.197**	4.780**
	(55.408)	(55.426)	(3.260)	(3.523)	(2.175)	(2.349)
City controls		Yes		Yes		Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.405	0.430	0.414	0.418	0.416	0.419
Observations	4,709	4,360	4,709	4,360	4,709	4,360

Table 4. Enforcement strength and bird diversity.

This table presents a subsample analysis to verify that improvements in biodiversity are driven by stricter enforcement of environmental laws following the EPB reforms. Cities are categorized into "stricter" and "looser" based on the intensity of changes in enforcement, specifically the difference in penalties between reform year (0) and two years pre-reform (-2). "Stricter" cities are those above the median in penalty increases, while "looser" cities fall below the median. The regression models follow Table 2, where the dependent variables are bird species and bird observation rates. The key explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year t. Control variables are identical to columns 3 and 6 of Table 2. All regressions include city and year fixed effects. Both subsamples encompass around 113 cities from 2003 to 2019 in China. The *Diff p-values* refer to the p-value of the suest test, which compares the coefficients across different models. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	Bird species		Birds obs.rates	
	Stricter	Looser	Stricter	Looser
	1	2	3	4
	Diff p-value: 0.042		*Diff p-value: 0.158*	
Post reform	23.021***	8.649	50.565**	16.689
	(8.756)	(7.214)	(20.714)	(18.113)
City controls	Yes	Yes	Yes	Yes
Birdwatching controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
Birdwatching account FE			Yes	Yes
R-squared	0.801	0.802	0.186	0.368
Observations	672	677	17,590	17,780

Table 5. Pollution types and bird diversity.

This table presents the results of an analysis examining the impacts of penalties associated with four types of pollution—air, water, solid waste, and industrial noise—on local bird species richness (panel A) and abundance (panel B). Cities are categorized into "stricter" (above median) and "looser" (below median) subsamples based on the total number of penalties imposed for these pollution types. The "strictness in enforcement" or "increase in penalties" is calculated as the difference in the number of penalties between the reform year 0 and the year -2. The regression models follow Table 2. The dependent variable in Panel A is *bird species,* and the dependent variable in Panel B is *bird observation rate*. The key explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year t. Control variables are identical to columns 3 and 6 of Table 2. All regressions include city and year fixed effects. Both subsamples encompass around 113 cities from 2003 to 2019 in China. The *Diff p-values* refer to the p-value of the suest test, which compares the coefficients across different models. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

Panel A. Bird species (city level)

	Air pollution		Water pollution		Solid waste		Industrial noise	
	Stricter	Looser	Stricter	Looser	Stricter	Looser	Stricter	Looser
	1	2	3	4	5	6	7	8
	Diff p-value: 0.031		*Diff p-value: 0.288*		*Diff p-value: 0.025*		*Diff p-value: 0.432*	
Post reform	25.516***	3.672	13.538	1.558	25.233**	-2.332	19.510*	4.241
	(9.668)	(8.176)	(9.359)	(7.836)	(9.826)	(7.856)	(11.374)	(12.056)
City and birdwatching controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.798	0.826	0.784	0.853	0.794	0.828	0.819	0.833
Observations	677	637	655	552	706	617	527	394

Panel B. Birds observation rates (event level)

	Air pollution		Water pollution		Solid waste		Industrial noise	
	Stricter	Looser	Stricter	Looser	Stricter	Looser	Stricter	Looser
	1	2	3	4	5	6	7	8
	Diff p-value: 0.405		*Diff p-value: 0.980*		*Diff p-value: 0.315*		*Diff p-value: 0.615*	
Post reform	31.520*	25.294	33.002*	20.881	33.205*	19.016	15.993	37.708
	(16.895)	(19.814)	(17.048)	(28.843)	(17.165)	(15.822)	(10.796)	(25.607)
City and birdwatching controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.176	0.376	0.175	0.455	0.175	0.450	0.211	0.152
Observations	22,016	12,819	20,980	11,626	22,588	12,316	20,935	9,315

Table 6. Local protectionism: Penalties on local firm vs. non-local firms.

This table explores the heterogeneous impacts of the EPB reforms on environmental penalties imposed on local versus non-local firms. We identify a firm as local if its registration county is identical to the EPB county. We utilize two dependent variables to measure environmental penalties: the number of penalties and the total fine amount (in million yuan). The key explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year *t*. Control variables are identical to column 2 of Table 2. All regressions include city and year fixed effects. The analysis encompasses 277 cities from 2003 to 2019 in China. The *Diff p-values* refer to the p-value of the suest test, which compares the coefficients across different models. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	Number of penalties		Total fine amount	
	Local	Non-local	Local	Non-local
	1	2	3	4
	Diff p-value: 0.010		*Diff p-value: 0.056*	
Post reform	116.945**	-4.750	5.044*	-0.174
	(47.976)	(7.771)	(2.836)	(0.612)
City controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
R-squared	0.383	0.313	0.331	0.242
Observations	4,360	4,360	4,360	4,360

Table 7. Central protectionism: SOE vs. POE.

This table explores the heterogeneous impacts of the EPB reforms on environmental penalties imposed on state-owned enterprises (SOEs) versus privately owned enterprises (POE). The firm ownership types are obtained from *tianyancha.com*. A firm is defined as an SOE if *tianyancha.com* labels it as state-owned, and as a POE otherwise. We utilize two dependent variables to measure environmental penalties: the number of penalties and the total fine amount (in million yuan). The key explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year *t*. Control variables are identical to column 2 of Table 2. All regressions include city and year fixed effects. The analysis encompasses 277 cities from 2003 to 2019 in China. The *Diff p-values* refer to the p-value of the suest test, which compares the coefficients across different models. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

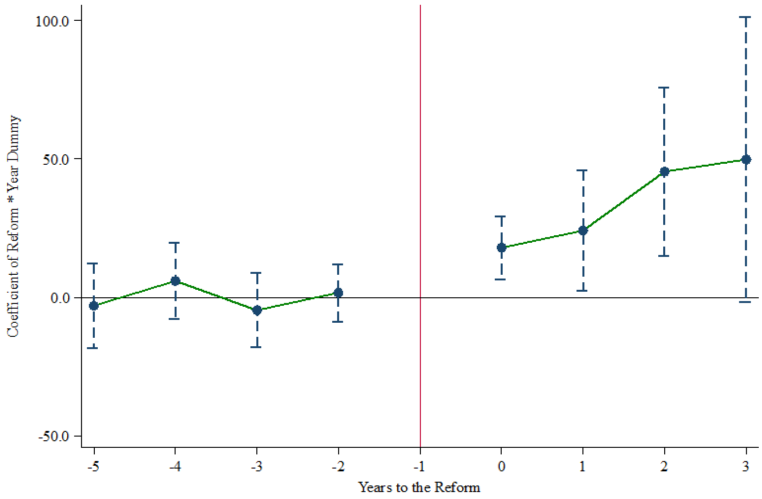
	Number of penalties		Total fine amount	
	SOE	POE	SOE	POE
	1	2	3	4
	Diff p-value: 0.023		*Diff p-value: 0.034*	
Post reform	1.049	128.043**	-0.235	7.370**
	(3.207)	(53.383)	(0.266)	(3.423)
Controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
R-squared	0.341	0.430	0.209	0.414
Observations	4,360	4,360	4,360	4,360

Table 8. Green patent applications by firms.

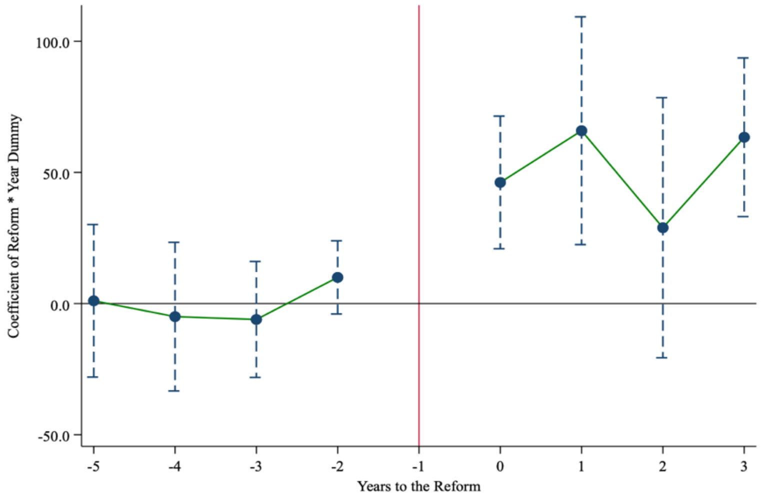
This table examines the heterogeneous impacts of the EPB reforms on firms' green initiatives, measured by the number of green patents firms apply for. Column 1 presents results for the full sample, which includes all locally registered firms. Column 2 focuses on state-owned enterprises (SOE), while column 3 provides results specifically for privately owned enterprises (POE). The key explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year *t*. Control variables are identical to column 2 of Table 2. All regressions include city and year fixed effects. The analysis encompasses 277 cities from 2003 to 2019 in China. The *Diff p-values* refer to the p-value of the suest test, which compares the coefficients across different models. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	#Green patents applied		
	All (local) firms	SOE	POE
	1	2	3
		Diff p-value: 0.041	
Post reform	74.850**	1.158	41.400**
	(32.803)	(1.208)	(19.915)
City controls	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes
R-squared	0.753	0.673	0.708
Observations	4,360	4,360	4,360

Online Appendix



Panel A. Bird species



Panel B. Bird observation rate

Figure A1. Parallel trends on bird diversity: TWFE.

Notes: This figure illustrates the pre- and post-trends in the effect of EPB reforms on bird diversity. The coefficients (with 95% confidence intervals) are derived from regressing the bird species (Panel A) and bird observation rate (Panel B) on relative-to-reform year dummies for the period between 2003 and 2019, using the TWFE estimation method. In the figures, "year -1," or the year immediately preceding the reform, is set as the reference year. "year-5" indicates five years or more prior to the reform, and "year 3" signifies three or more years after the reform. The regressions include city-level and birdwatching event controls (see Table 2), as well as city and year fixed effects.

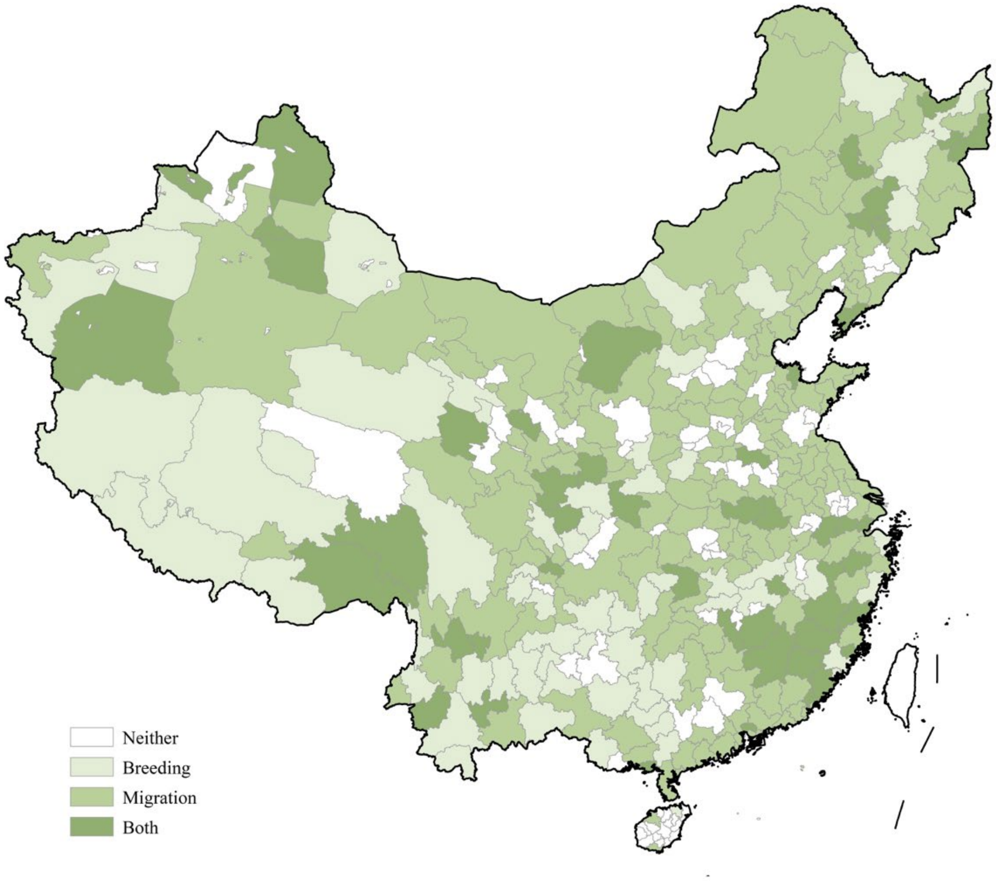
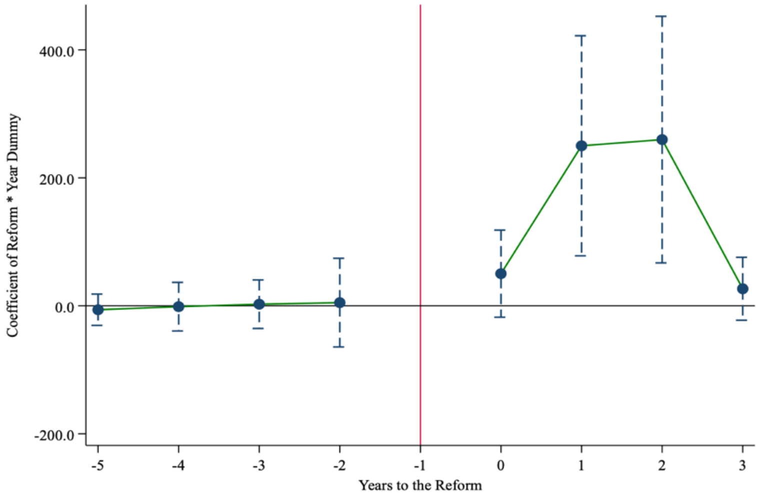
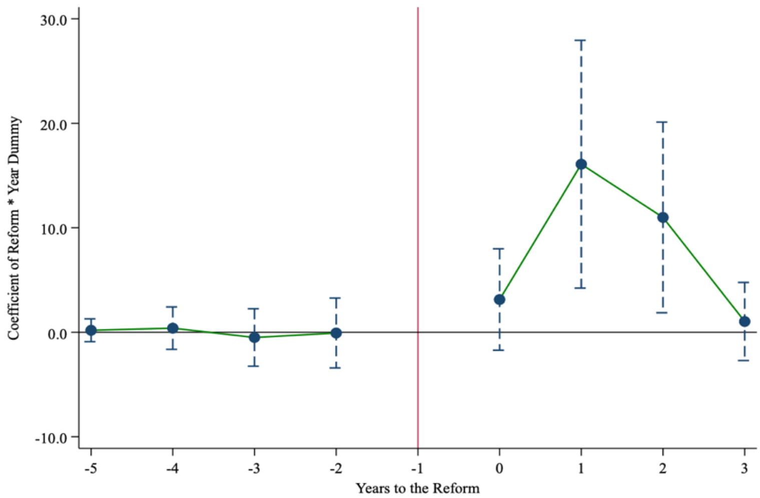


Figure A2. Distributions of breeding and migration areas.

Notes: This figure illustrates the breeding areas and stopovers for migratory birds from the National Action Plan for the Protection of Bird Migration Routes (National Forestry and Grassland Administration 2022).



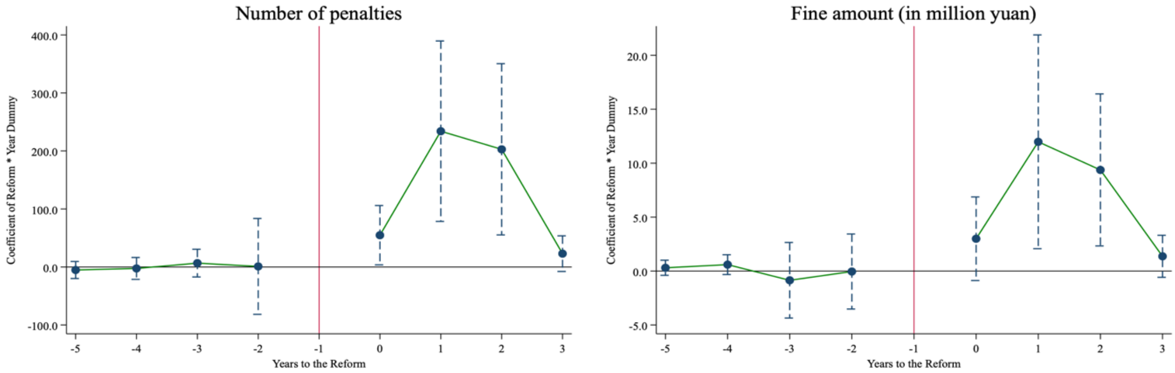
Panel A. Number of penalties



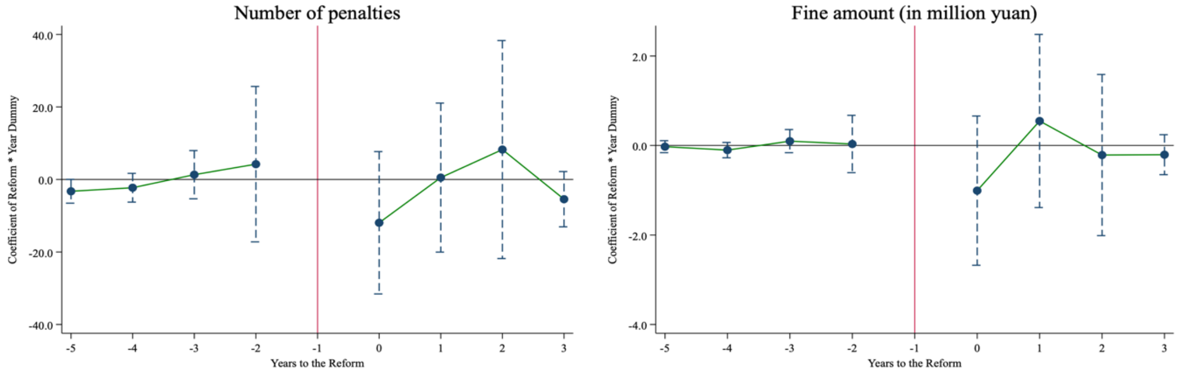
Panel B. Fine amount (in million yuan)

Figure A3. Parallel trends on penalty: TWFE.

Notes: This figure shows the pre- and post-trends in the effect of EPB reforms on penalties. The coefficients (with 95% confidence intervals) are obtained from regressing the number of penalties (Panel A) and the total fine amount in million yuan (Panel B) on relative-to-reform year dummies for the period between 2003 and 2019, using the TWFE estimation method. In the figures, "year -1," or the year immediately preceding the reform, is set as the reference year. "year-5" indicates five years or more prior to the reform, and "year 3" signifies three or more years after the reform. The regressions include city-level controls (see Table 2), as well as city and year fixed effects.



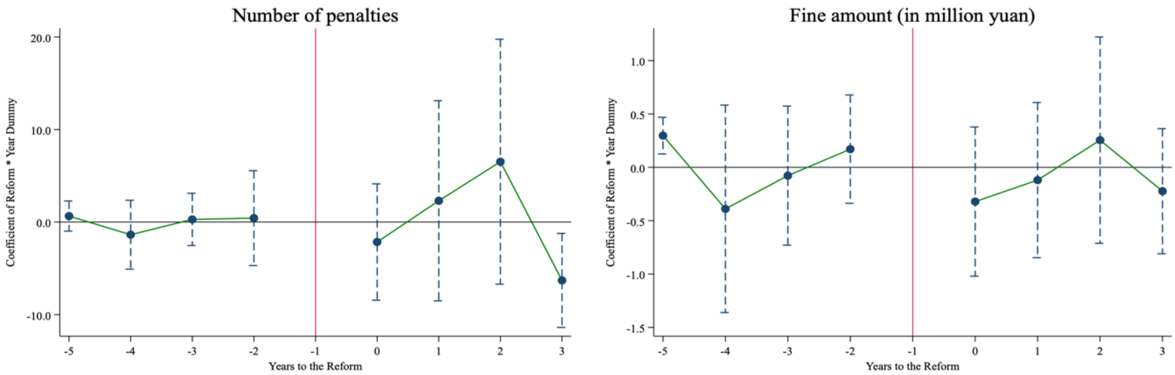
Panel A. Local firms



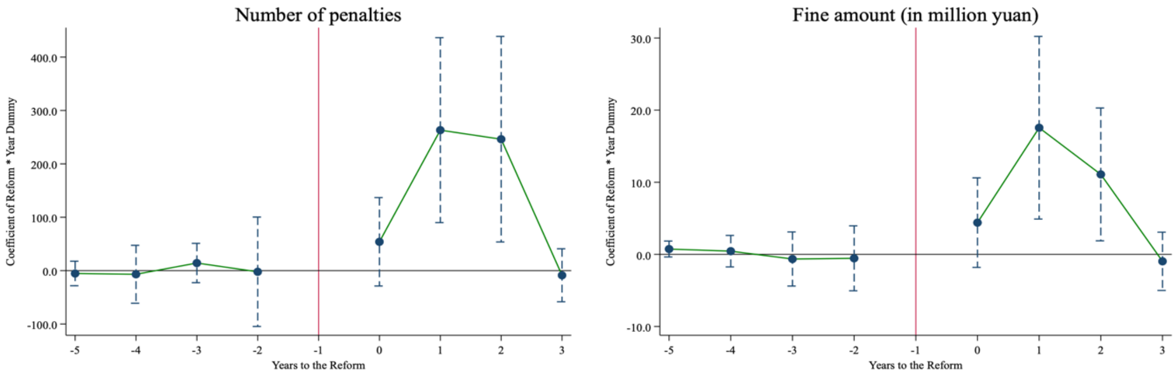
Panel B. Non-local firms

Figure A4. Local protectionism: Penalties on local vs. non-local firms.

Notes: This figure shows the pre- and post-trends in the effect of EPB reforms on penalties while dividing the sample into local (Panel A) and non-local (Panel B) firms. The coefficients (with 95% confidence intervals) are obtained from regressing the number of penalties and the total fine amount (in million yuan) on relative-to-reform year dummies for the period between 2003 and 2019, using the Sun and Abraham (2021) method. In the figures, "year -1," or the year immediately preceding the reform, is set as the reference year. "year-5" indicates five years or more prior to the reform, and "year 3" signifies three or more years after the reform. These regressions include city-level controls (column 2 of Table 2 for reference), as well as city and year fixed effects.



Panel A. SOE



Panel B. POE

Figure A5. Central protectionism: Penalties on SOEs vs. POE.

Notes: This figure shows the pre- and post-trends in the effect of EPB reforms on penalties while dividing the sample into SOEs (Panel A) and POEs (Panel B) firms. The coefficients (with 95% confidence intervals) are obtained from regressing the bird species, bird observation rate, the number of penalties, and the total fine amount (in million yuan) on relative-to-reform year dummies for the period between 2003 and 2019, using the Sun and Abraham (2021) method. In the figures, “year -1,” or the year immediately preceding the reform, is set as the reference year. “year-5” indicates five years or more prior to the reform, and “year 3” signifies three or more years after the reform. These regressions include city-level controls (Table 2 for reference), as well as city and year fixed effects.

Table A1. Variable definitions.

	Definition
Independent variables, 2003-2019	
Post Reform (dummy)	A dummy that equals one if the city has experienced EPB reform on or after year *t*.
Birdwatching at city-year level, 2003-2019	
Bird species	The total number of unique bird species observed in a city-year.
Total # birdwatching events	The total number of birdwatching records in a city-year.
Total effort hours	The total observation duration (effort hours) of all birdwatching records in a city-year. The effort hour of each event is calculated as the time difference between observation start and end times.
Birdwatching at event level, 2003-2019	
Bird observation rate (# birds observed per hour)	The average number of birds observed per hour in each birdwatching event.
Effort hours per event	Observation duration, calculated as the time difference between observation start and end times.
Enforcement at city-year level, 2003-2019	
Number of penalties	Total number of environmental penalties within a city-year. An environmental penalty is an administrative sanction imposed on firms that violate environmental protection laws.
Fine amount (in million yuan)	Total amount of environmental penalty fines within a city-year. Environmental penalties can include fines, production stoppages, and other specific measures.
Fine amount (in million yuan, deflate to 2003)	Total amount of environmental penalty fines within a city-year deflated with annual inflation rate, using the year 2003 as a benchmark year.
City-year controls, 2003-2019	
Population density (in 1,000 persons/sq.km)	Population size (in 1,000 persons) scaled by land area (squared kilometers) in each city-year.
Urbanization rate (%)	The proportion of population residing in urban areas in each city-year.
GDP (in billion yuan)	Gross Domestic Product in each city-year.
Primary industry output (scaled by GDP, %)	The output of primary industry output scaled by GDP in each city-year.
Secondary industry (scaled by GDP, %)	The output of secondary industry output scaled by GDP in each city-year.
Real estate investment (in billion yuan)	Total investment in real-estate industry scaled by GDP in each city-year.
Green space ratio (%)	The fraction of green space area over total land area in each city-year.
Temperature (°C)	Average temperature of each city-year. The original data is at monthly frequency.
Precipitation (mm)	Average depth of water from rain, snow, sleet, or hail in each city-year, measured in millimeters. The original data is at monthly frequency.
Wind speed (m/s)	Average wind speeds synthesized from latitudinal and longitudinal wind vectors in each city-year, measured in meters per second. The original data is at monthly frequency.
Pollution at city-year level	
Air quality, 2014-2019	
AQI (ug/m3)	A numerical scale ranging from 0 to 500 that indicates the level of air pollution. Higher values correspond to greater pollution levels and health concerns.
PM2.5 (ug/m3)	Concentration of fine inhalable particles with diameters of 2.5 micrometers or smaller, measured in micrograms per cubic meter of air.
PM10 (ug/m3)	Concentration of inhalable particles with diameters of 10 micrometers or smaller, measured in micrograms per cubic meter of air.
Number of slight pollution days	The count of days within a city-year when the AQI falls within the ‘Moderate’ category (typically AQI 101–150).
Number of median pollution days	The count of days within a city-year when the AQI falls within the ‘Unhealthy for Sensitive Groups’ category (typically AQI 151–200).
Number of heavy pollution days	The count of days within a city-year when the AQI falls within the ‘Unhealthy’ category (typically AQI 201–300).
Number of severe pollution days	The count of days within a city-year when the AQI falls within the ‘Very Unhealthy’ or ‘Hazardous’ categories (typically AQI 301 and above).
Pollutants, 2003-2019	
Wastewater (in million tons)	The total volume of water that has been used and discharged by households, industries, and other sources within a specified period.

SO2 (in 1,000 tons)	The total mass of sulfur dioxide—a pungent, colorless gas produced primarily from burning fossil fuels—that is emitted into the atmosphere over a specified period.
Soot (in 1,000 tons)	The total mass of fine black particles, primarily composed of carbon, resulting from incomplete combustion of hydrocarbons, emitted into the atmosphere over a specified period.
NOx (in 1,000 tons),	The total mass of nitrogen oxides—a group of reactive gases including nitric oxide (NO) and nitrogen dioxide (NO_2)—produced from combustion processes, emitted into the atmosphere over a specified period.
Green patent at city-year level, 2003-2019	
Number of green patents applied	The total count of patent applications filed by all firms within a city-year
Number of green patents applied, POE	The total count of patent applications filed by Privately Owned Entreprises within a city-year.
Number of green patents applied, SOE	The total count of patent applications filed by State-Owned-Entreprises within a city-year.

Table A2. eBird sample with more controls.

This table replicates the regression in Table 2, except that the birdwatching sample is from eBird.com alone. This sample allows for the inclusion of two additional control variables: effort distance (distance traveled during the observation period, in km) and number of observers in each birdwatching event. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	Bird species (at city-year level)		Bird observation rate (at event level)		
	1	2	3	4	5
Post reform	27.553***	17.227***	60.569**	60.418**	46.632**
	(7.719)	(6.377)	(28.022)	(28.245)	(22.004)
Total # observers		0.023			
		(0.051)			
Total effort distance		-0.020			
		(0.039)			
# observers of the event				-0.005	-0.634
				(0.906)	(0.904)
Effort distance of the event				1.488**	1.549*
				(0.716)	(0.797)
City controls	Yes	Yes	Yes	Yes	Yes
Birdwatching controls	Yes	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes
Birdwatching account FE					Yes
R-squared	0.712	0.783	0.269	0.270	0.353
Observations	1,020	1,020	17,045	17,045	16,575

Table A3. Alternative sample, 2014-2019.

This table replicates the regression in Table 2, except that the sample period spans from 2014 to 2019. Standard errors are clustered at the city level and are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

	Bird species (at city-year level)			Bird observation rate (at event level)			
	1	2	3	4	5	6	7
Post reform	10.199*	16.436***	12.176**	18.657*	29.075*	28.736*	29.563**
	(5.640)	(6.313)	(5.883)	(10.819)	(15.561)	(15.581)	(12.344)
City controls		Yes	Yes		Yes	Yes	Yes
Birdwatching controls			Yes			Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Birdwatching account FE							Yes
R-squared	0.835	0.842	0.864	0.243	0.247	0.247	0.349
Observations	1,037	919	919	37,868	32,909	32,909	32,197

Table A4. Placebo test: neighbor cities' reforms.

This table examines the impact of neighboring cities' EPB reforms on local bird diversity. The dependent variable, *bird species,* refers to the total number of unique bird species observed in a city-year, and the regressions are performed at the city-year level. The explanatory variable, *post reform*, is a dummy variable that equals one if the city has experienced EPB reform on or after year *t*. *post neighbor reform* is a dummy variable that equals to one if any of city *i*'s adjacent cities have undergone EPB reforms in or before year *t*. Control variables are identical to those in Table 2. All regressions include city and year fixed effects. The full sample comprises approximately 40,000 birdwatching records from 277 cities in China between 2003 and 2019. City-years without any birdwatching activities are omitted in the regression. Standard errors clustered at the city level are reported in parentheses. *, **, and *** indicate significance at 10%, 5% and 1%, respectively.

Panel A. Bird species (city level)

	Bird species (at city-year level)					
	1	2	3	4	5	6
Post reform	15.587*	23.181***	17.424**			
	(7.968)	(8.368)	(7.212)			
Post neighbor reform	1.700	1.896	-2.581	5.076	7.452	1.585
	(7.804)	(8.080)	(6.612)	(7.366)	(7.502)	(6.126)
City controls		Yes	Yes		Yes	Yes
Birdwatching controls			Yes			Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.698	0.710	0.776	0.696	0.707	0.774
Observations	1,504	1,357	1,357	1,504	1,357	1,357

Panel B. Birds observation rates (event level)

	Bird observation rate (at event level)					
	1	2	3	4	5	6
Post reform	23.487**	29.602**	29.231**			
	(11.453)	(12.928)	(12.924)			
Post neighbor reform	15.252*	21.338*	20.825*	13.470	21.109*	20.584*
	(9.096)	(11.738)	(11.733)	(8.844)	(12.061)	(12.041)
City controls		Yes	Yes		Yes	Yes
Birdwatching controls			Yes			Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.240	0.244	0.244	0.239	0.242	0.243
Observations	40,534	35,470	35,470	40,534	35,470	35,470

Table A5. Migrant vs. non-migrant cities and birds.

This table examines the heterogeneous effects of EPB reforms on bird diversity across migratory and non-migratory bird groups. Panel A contrasts migration areas (stopover sites for migratory birds) with breeding areas. Columns 1 and 3 focus on cities hosting a higher number of migratory birds, while columns 2 and 4 include cities supporting more breeding birds. The regression models follow those in columns 3 and 6 of Table 2, except the sample is divided by city type. Panel B compares effects on migratory versus resident bird species. Columns 1 and 3 focus on migratory bird species, while columns 2 and 4 focus on resident bird species. The regression models follow those in columns 3 and 6 of Table 2, except that the dependent variables are split into two bird categories. All regressions include city and year fixed effects. *Diff p-values* refer to p-values from the suest test comparing coefficients across models. Standard errors are clustered at the city level and reported in parentheses. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Migration versus breeding areas

	Bird species		Birds obs.rates	
	Migration	Breeding	Migration	Breeding
	1	2	3	4
	Diff p-value: 0.005		*Diff p-value:0.212*	
Post reform	29.680***	-17.894	39.008*	16.230
	(9.992)	(11.387)	(20.597)	(16.011)
City and birdwatching controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
R-squared	0.806	0.878	0.257	0.199
Observations	720	296	24,929	5,588

Panel B. Migrant versus resident bird species

	Bird species		Birds obs.rates	
	Migrant	Resident	Migrant	Resident
	1	2	3	4
	Diff p-value: 0.079		*Diff p-value: 0.033*	
Post reform	10.626**	4.500*	28.455**	-0.164
	(4.679)	(2.498)	(13.671)	(0.937)
City and birdwatching controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
R-squared	0.778	0.759	0.258	0.128
Observations	1,338	1,298	34,671	32,375

Table A6. City-level pollution: Air quality.

This table examines the effects of the EPB reforms on air quality. The dependent variables are averaged city-year level air quality measures, sourced from CNRDS and available since 2014. AQI (column 1) is the Air Quality Index, a composite measure reflecting overall pollution levels; PM2.5 (column 2) represents fine particulate matter smaller than 2.5 microns (μg/m³); PM10 (column 3) captures particulate matter smaller than 10 microns (μg/m³). Columns 4–7 examine different degrees of pollution days within a city-year: slight pollution (column 4), moderate pollution (column 5), heavy pollution (column 6), and severe pollution (column 7). All regressions include city-level controls (as in column 2 of Table 2) and city and year fixed effects. Standard errors are clustered at the city level and reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Different air pollutant			Different degrees of pollution days			
	AQI	PM2.5	PM10	Slight	Median	Heavy	Severe
	1	2	3	4	5	6	7
Post reform	-1.900**	-1.992***	-2.683**	-3.532*	-4.547***	-2.144**	-0.805**
	(0.763)	(0.713)	(1.073)	(2.061)	(1.544)	(0.919)	(0.347)
City controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	City	City	City	City	City	City	City
R-squared	0.937	0.919	0.933	0.915	0.854	0.791	0.701
Observations	1,404	1,404	1,404	1,404	1,404	1,404	1,404

Table A7. City-level pollution: Pollutants.

This table examines the effects of the EPB reforms on different pollutants. The dependent variables are city-year level air and water pollutants, sourced from the Chinese City-Yearbook, available since 2003, except for NOx, which is available from 2017 onward. Wastewater (column 1) refers to the volume of polluted water discharged by industrial and municipal sources (measured in million cubic meters); SO_2 (column 2) represents sulfur dioxide emissions, a major contributor to acid rain and respiratory issues (measured in thousand tons); Soot (column 3) refers to particulate emissions from combustion processes, such as industrial and vehicle emissions, which impact air quality and health (measured in thousand tons); and NOx (column 4) represents nitrogen oxides, pollutants from combustion that contribute to smog and acid rain (measured in thousand tons). Panel A reports results for the full sample with data available from 2003, while Panel B restricts the sample period of 2014–2019, as the majority of cities underwent reform after 2014. All regressions include city-level controls (as in column 2 of Table 2) and city and year fixed effects. Standard errors are clustered at the city level and reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Full sample: 2003 (2017) - 2019

	Wastewater	SO2	Soot	NOx
	1	2	3	4
Post reform	-7.691	-6.638	-3.715	-0.252
	(5.931)	(5.908)	(2.724)	(0.628)
City controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
R-squared	0.824	0.805	0.606	0.959
Observations	4,205	4,207	4,199	581

Panel B. Majority of reforms period: 2014 - 2019

	Wastewater	SO2	Soot
	1	2	3
Post reform	-6.816**	-8.436***	-13.039***
	(2.690)	(3.039)	(4.495)
City controls	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes
R-squared	0.933	0.809	0.816
Observations	1,388	1,394	1,389

Table A8. City-level output: GDP.

This table examines the effects of the EPB reforms on city-level output, as measured by the logarithm of GDP and GDP growth rate. All regressions include city-level controls, except for GDP (as in column 2 of Table 2) and city and year fixed effects. Standard errors are clustered at the city level and reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	log(GDP)	log(GDP) (deflated)	GDP growth rate	GDP growth rate (deflated)
	1	2	3	4
Post reform	0.012	0.012	-2.387	-2.321
	(0.028)	(0.028)	(1.637)	(1.596)
City controls	Yes	Yes	Yes	Yes
City and Year FE	Yes	Yes	Yes	Yes
R-squared	0.982	0.980	0.116	0.105
Observations	4,360	4,360	4,343	4,343