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Biodiversity and happiness: Exploring the value of nature

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Abstract: The value of a more diversified ecosystem lies beyond nature itself and extends to the human world. It provides benefits, both physically and psychologically, to each individual living in the system. Following this argument, we develop an empirical framework examining the impacts of biodiversity on human well-being in China. Using bird diversity index as a proxy for biodiversity at the city-level, we find a significant positive relationship between biodiversity and self-reported happiness, even after accounting for individual and regional factors. In addition, we employ the establishment of new natural reserves as a quasi-natural experiment to construct a difference-in-differences (DID) model to demonstrate that improvements in biodiversity can indeed lead to higher levels of happiness. These findings underscore the value of nature in enhancing human well-being and highlight the need for policies to support biodiversity.

Keywords: Biodiversity; Happiness; Household survey; Nature capital; Social welfare

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1. Introduction

Biodiversity loss and ecosystem collapse are considered top of the three major long-term threats by the World Economic Forum (2024). Arguably, the world is now experiencing its sixth mass extinction (Cowie et al., 2022). According to the International Union for Conservation of Nature and Natural Resources (IUCN) Red List,[1] around 28% of species are listed as being threatened to extinction in 2021, and these losses have been proven irreversible. Regarding birds, for example, it has been found that "*we are losing birds at an unprecedented rate*".[2] Unlike previous rounds of extinction, the current wave is often considered to be driven by human activities (Ripple et al., 2017). Among others, human population growth and overconsumption are the primary factors behind this extinction (Ceballos et al., 2017). There are also other underlying reasons such as habitat destruction, land-use change, pollution, and climate change, all of which contribute to the declining trend of biodiversity.

In terms of natural capital, ecosystems provide tremendous value but often being ignored (Costanza et al., 1997). Fortunately, people have started to pay attention to the value of biodiversity, and efforts have been made to improve it (Christie et al., 2006). In 1992, the Convention on Biological Diversity (CBD) opens for signature, marking the start of international movements on the conservation of biodiversity. This multilateral treaty has led to the adoption of the Kunming-Montreal Global Biodiversity Framework (GBF), a historical and critically important move to develop clear strategic plans wherein all parties agree to establish national targets and commitments. One notable endeavor of the GBF is the awareness-raising campaign involving efforts to help the public realize the importance of biodiversity. Consequently, more people have started to favor biodiversity conservation, for example, in the US (Manfredo et al., 2021).

Biodiversity conservation is a global issue that is relevant to people worldwide. The value of biodiversity encompasses physical and psychological factors. Hanley and Perrings (2019), for example, explain how biodiversity may generate economic value directly and indirectly. Islam et al. (2019) adopt an inclusive wealth approach to provide a cross-country valuation of ecosystem

[1] IUCN Red List of Threatened Species
[2] The 2023 Red List update reveals hope for birds in crisis - BirdLife International

conservation. In addition, scholars have recognised that humanity needs biodiversity, and a better natural environment can improve human well-being (Lynch et al., 2023). The empirical evidence in the existing literature suggests that environmental degradation can lead to negative impacts on the happiness of people (Ferrer-i-Carbonell and Gowdy, 2007). Harvey et al. (2020), in addition, highlight the psychological benefits of biodiversity for school children. While the logic behind this relationship appears obvious, more research examining the impacts and attempting to understand the underlying mechanisms remains necessary, particularly for countries in different development stages and with distinctive cultural variations.

For China, one of the largest developing countries in the world, has encountered severe environmental challenges throughout its growth trajectory. As a vast country with great geographical variations, China is one of the most biodiverse countries, with over 30,000 species of higher plants and more than 6,300 species of vertebrates (Xu et al., 2016). These abundant species cover various types of ecosystems, including forests, wetlands, grasslands, deserts, and alpine systems, making China a crucial region for global biodiversity conservation. All elements contributing to biodiversity loss can be found in China, and significant biodiversity losses have surfaced across various regions (e.g. Lu et al., 2020).

In recent years, China has placed growing emphasis on biodiversity conservation (e.g. Wang et al., 2020). These efforts are evident in the establishment of nature reserves and national parks, as well as the development and implementation of the 'China Biodiversity Conservation Strategy and Action Plan (2023–2030)'. Notably, in the 2024 Third Plenary session of the 20th Central Committee of the Communist Party of China, the 'Enhancement of coordination mechanisms for biodiversity protection' was given a priority status, highlighting the country's policy direction in advancing biodiversity conservation.

Nevertheless, China still faces considerable challenges in biodiversity conservation. China has vast spatial variations and significant gaps in economic development across regions, and biodiversity conservation has exhibited clear regional differences as well (Lu et al., 2020). Local governments have clear incentives to prioritize to economic growth at the expense of ecosystems (Ye et al., 2021). These local officials frequently devote more attention to visible economic benefits, while neglecting the unobservable social benefits (e.g. happiness) of the local community. Thus, examining the impacts of biodiversity on social welfare and economics is useful to support policy designs.

In fact, ecosystem conservation in China has been improving significantly as a consequence of continuous government interventions (Yin et al., 2021). From the literature, we can see that enhanced environments and greater biological diversity can exert positive impacts on how people feel. For example, MacKerron and Mourato (2013) provide evidence that people are happier in natural environments compared to urban environments. Bonasia et al. (2022) demonstrate a direct link between happiness and environmental protection using data from 19 European countries. Most of these studies focus on developed economies and pay more attention to general environmental effects. However, it remains unclear whether the changes in China yield any social benefits and to what extent they have improved human well-being, resulting a need for an in-depth empirical analysis.

This paper therefore aims to explore this issue in China and develops an empirical framework to test the impacts of biodiversity on happiness. To be specific, we use bird abundance index and bird richness index as proxies for biodiversity at the city-level; this is then used to explain the impacts on self-reported happiness in China. The individual-level data is collected from a nationwide household survey, namely the China Household Finance Survey (CHFS). We use five rounds of the survey from 2011 to 2019 (bi-annually) for the empirical analysis. After controlling individual and regional characteristics, the empirical results offer strong evidence supporting a positive role of biodiversity on happiness. In addition, to confirm the causal relationship, we use the newly established national reserves as an experiment to develop a DID model. The nature reserves appear to improve biodiversity conservation (Beckline and Yujun, 2014), leading to higher levels of well-being. Possible channels that link biodiversity with happiness are also examined.

Overall, our research makes several key contributions to the understanding of biodiversity and its impact on human well-being. First, it offers a comprehensive analysis of the spatiotemporal patterns of bird diversity across Chinese cities, which is crucial for understanding local biodiversity dynamics in a rapidly urbanization context. These findings highlight the severe state of biodiversity in China and offer a scientific basis for policymakers to identify priority areas for conservation, guiding targeted decisions in biodiversity protection and city planning.

Second, this work enhances the understanding of the relationship between biodiversity and human well-being. While substantial research has explored the non-material impacts of nature (Díaz et al., 2018; Remme et al., 2021; Pascual et al., 2023), knowledge about biodiversity's effects on happiness remains limited (Methorst et al., 2021). Our study provides empirical evidence of a positive relationship between bird diversity and happiness. The findings and associated mechanism analyses enrich our understanding of how biodiversity improvements can enhance human well-being.

Third, this study provides new evidence valuing the importance of nature, particularly for the largest emerging economy. China has achieved significant progress in terms of environmental protections while also maintaining economic growth over the past decades; meanwhile, stronger commitments regarding climate change and biodiversity have been made for the future. Identifying both the economic and non-economic benefits of these efforts carries important policy implications.

The structure of this paper is as follows: Section 2 reviews the relevant literature regarding how to measure biodiversity and establish its connections with happiness. Section 3 explains the construction of the biodiversity indexes and other main variables. Section 4 illustrates the model. Section 5 reports the empirical results and discusses the main findings. The last section concludes with additional discussions of possible implications.

2. Literature review

Biodiversity, a term first used by Wilson (1989), refers to the variety of life at both evolutionary and ecological levels (Colwell, 2009). The concept has a lengthy history but has evolved continuously. The richness of species is frequently discussed by ecologists and conservation biologists, while functional diversity refers to species fulfilling different functional roles in a community. The complexity of these fundamental differences has made it difficult to establish a consistent definition and associated measurements (DeLong, 1996).

Izsák and Papp (2000) argue that typical biodiversity indices are often based on species differences but that they are unable to cover abundances as the traditional ecological diversity measures.

Biodiversity has a multidimensional nature, and there is a need to construct an optimal measure of biodiversity to maximize information and produce it in a compact form (Lyashevska and Farnsworth,2012). Bandeira et al. (2013) show that the typical biodiversity indices can mathematically converge under certain assumptions. They suggest that the eight indices can be classified into three groups, and the convergence can reduce the number of indices needed. Nonetheless, the subtle differences in meanings of the term 'biodiversity' matter more to scientists and hold no crucial differences to economists and social planners. Moreover, although fully capturing the complexity of biodiversity is almost impossible, Purvis and Hector (2000) suggest that a particular facet can be useful.

Regarding the debate about the definition of biodiversity, the value of biodiversity is generally agreed upon among researchers, leading to a consensus in the global community to address the loss of biodiversity (Díaz et al., 2018). For instance, Pascual et al. (2023) propose a four-tier framework to capture the value of nature for human societies: worldviews and knowledge systems, broad values, specific values, and value indicators. However, one has to realize that enhancing or even maintaining the level of biodiversity is costly. Pearce (2007) contends that the world is not truly invested in preserving biodiversity, as demonstrated by the gap between actual expenditures and the stated willingness to pay. The cost of biodiversity losses must be recognized, and equally, it is important to help decision makers understand the economic benefits of biodiversity conservation (Hanley and Perrings, 2019). Paul et al. (2020) investigate the functional relationship between biodiversity and its economic value. While these economic analyses of the value of biodiversity are abundant, more incentives are needed for the public to understand the value of improving biodiversity and engage in the efforts of conservation. Novacek (2008) highlights the importance of engaging the public in biodiversity conservation. In other words, understanding the non-economic or indirect value of biodiversity from the human side is also critical.

Some recent scholars have started to investigate the socio-economic impacts of biodiversity. Biodiversity conservation is expected to involve non-negligible management and opportunity costs. Ferris and Frank (2021) find that the 1990 protection of the Northern Spotted Owl led to a 28.1% decrease of employment in the United States. Chen (2021) argues that the economic benefits of protecting the ecosystem are far more significant than the cost of conservation. Similarly, Taylor and Druckenmiller (2022) estimate the crucial role of natural capital in flood control and disaster mitigation, finding that the social value provided by flood prevention from U.S. wetlands could offset the economic costs of wetland conservation. In China, Cheng et al. (2023) report that biodiversity conservation initiatives have a positive effect on the overall development index of households. Meanwhile, conservation policies can lead to a significant increase in the bond yields of Chinese cities (Chen et al., 2024).

Recently, a thriving literature has emerged exploring the relationship between biodiversity and human well-being (e.g., Naeem et al., 2016). Adjei and Agyei (2015) confirm the positive effect of biodiversity on happiness through research concerning visitors to North Wales. Schebella et al. (2019) show that perceived biodiversity can increase self-reported well-being in Australia. In addition, other studies have further emphasized the contribution of biodiversity to residents' mental and physical health (e.g., Jones, 2023; Methorst, 2024), indicating that a diversed natural environment can provide greater emotional benefits, promote social interactions, and thus enhance human well-being.

In China, biodiversity conservation has become a major concern in recent years, especially after the 15^{th} CBD hosted in Kunming. Due to rapid economic growth, biodiversity loss has become a salient issue in China (Liu et al., 2003). Both governments and scientists have made efforts to restore degraded ecological systems and have made sustainable development a top priority alongside economic growth (Wang et al., 2020). By reviewing the research on biodiversity sciences, Mi et al. (2021) illustrate the rapid progress of biodiversity research in China, rendering the country a global leader in this area.

As the economy has advanced in China, human well-being has garnered more attention. Knight and Gunatilaka (2011), for example, examine whether the remarkable economic growth in China improve life satisfaction. Brockmann et al. (2009) discuss '*The China Puzzle*', referring to the phenomenon wherein happiness has declined alongside growing income. Not surprisingly, when economic conditions improve, people tend to demand more leisure and to care more about their quality of life (Wei et al., 2015). The value of nature has become more prominent in the literature, but the results are controversial. For instance, Cheng (2020) uncover a significant negative effect of green space on happiness in urban China, although this relationship changes when income levels increase. Using the Chinese General Social Survey (CGSS), He et al. (2022) examine the association between greenspaces and happiness in China, and they also find that this relationship varies based on family types. Both studies benefit from the availability of large nationwide household surveys, which provide detailed demographic information for the empirical analysis.

One of the main challenges of the relevant empirical research is that measuring biodiversity is challenging. Most species on Earth have not been formally described (known as the Linnaean Shortfall), and little is known about the geographical distribution of most species (known as the Wallacean Shortfall) (e.g., Brown and Lomolino 1998; Lomolino 2004). Consequently, many studies often rely on a small subset of species that are implicitly or explicitly considered as proxies for the overall biodiversity (Simberloff, 1998). A widely adopted approach is to use species from a single well-known taxonomic group, such as birds as a surrogate (e.g., Gregory et al., 2003; Butchart et al., 2010). For example, the well-known Wild Bird Index (WBI) is part of the Streamlining European Biodiversity Indicators framework (Biała et al., 2012). Additionally, the annual Bird Diversity Assessment Index released by the China Birdwatching Center continuously monitors bird conservation across provincial administrative regions (CBA, 2023).

Due to their ease of observation and presence in various habitats, birds serve as effective indicators for monitoring biodiversity changes (Jetz and Rahbek, 2002; Robinson, 2019; Wauchope et al., 2022). Additionally, birds have broad public appeal and the potential for revenue from birdwatching activities (US Fish and Wildlife Service, 2013), which is the reason why many biodiversity monitoring and conservation programs focus on them. For example, the eBird, the Pan-European Common Bird Monitoring Scheme, the European Bird Census Committee, and the China Bird Report. Therefore, focusing on bird species holds significant research value. Based on these discussions and following the existing literature, we also use bird species in China as a proxy to measure biodiversity. It is measured at the city level and then used to investigate the impacts of biodiversity on human well-being (i.e. happiness).

3. Data construction

3.1 Bird diversity index

As what we have discussed above, birds serve as an ideal indicator group for assessing biodiversity. This study utilizes bird observation data from the China Bird Report (CBR), currently the largest citizen science platform for bird monitoring in China. It covers 94% of the national bird species and 94.3% of the county-level administrative regions (CBA, 2023). Each of the user reports in the dataset is referred to as an 'observation checklist', which includes details such as observation time, location, bird species, and counts. Using text mining techniques, we collect nearly 8 million bird records from approximately 400,000 observation checklists spanning the period between 2005 and 2023.

Following Sun et al. (2022), we match the bird classifications with the data in the CBR dataset and undertake several processing steps on the original dataset. First, the reference list for recording bird species in the CBR changed in 2014. Specifically, prior to 2014, the CBR used the 'Field Guide to the Birds of China,' whereas from 2014 onward, it has adopted the 'China Bird Report: Checklist of Birds 3.0.' To ensure consistency in data evaluation, we retain only the species common to both versions, resulting in approximately 1,300 species. Second, to get the city-year bird diversity index in China, we exclude observation checklists where the observation does not start and end in the same year. Third, considering potential observational errors, we limit the number of individual species recorded in a single checklist to a range of 1 to 1,000. Fourth, the transition from the old to new databases in 2014 resulted in a noticeable decline in both the number of observation checklists and bird species for that year compared to others, thus we treat the 2014 data as missing. Fifth, to determine the spatial distribution of birds, we geocode observation locations at the city level. Finally, we retain information on the number of observation checklists, bird species counts, and individual counts for each year and city.

Two indicators of bird diversity are used in this paper, namely, the bird abundance index and the bird richness index (see, e.g., Scherber et al., 2010; Rosenberg et al., 2019; Bai and Tang, 2024). The bird abundance index reflects the average number of individual birds per checklist at the city-year level. The bird richness index measures the average number of unique bird species per checklist at the city-year level. We exclude cities with significant missing data (more than 9 years of missing) and interpolate the remaining missing data. Ultimately, we obtain a balanced panel data on the bird abundance index and the bird richness index for 204 Chinese cities (municipalities and prefecturelevel cities) from 2005 to 2023. In the empirical section, considering that the key explanatory variable, happiness, pertains to the years 2011-2019, we also limit the subsequent use of the bird diversity indices to this timeframe.

Fig. 1 provides the distribution characteristics of the bird abundance index across Chinese cities. From 2011 to 2019, both the median (horizontal line in the boxplot) and the mean (purple dots) of the index exhibit a declining trend. The average index level across all cities and for the entire sample is 216.437, but the number is 255.805 in 2011, which decreases to 147.667 in 2019. This trend aligns with the ongoing global threat of species endangerment and extinction highlighted by the IUCN Red List. Furthermore, the bird abundance index is unevenly distributed across cities.

[Insert Figs. 1-2 about here]

To illustrate the city-level differences, we also provide further information about the distribution of the index in 2011 and 2019 (see Fig. 2). The logarithmic transformation is applied to the bird abundance index and used in the subsequent empirical analysis. In Fig. 2, the cities are linked with their provinces, which are then classified into seven groups according to geographical locations. We are able to identify clear regional differences in the bird diversity during this sample period. Cities in the north and the east of China have higher levels of diversity, but cities in the northeast and southwest regions have experienced significant improvements. Overall, most cities in the sample exhibit a decrease in bird populations, underscoring the challenges that Chinese cities face in biodiversity conservation.

3.2 Happiness

For individual-level information regarding happiness and other demographic variables, we extract information from the CHFS dataset. This is a biannual national household survey that began in 2011, and to date, five rounds of data have been released for 2011, 2013, 2015, 2017, and 2019, which are then used in the empirical study here. The CHFS survey covers samples in 29 provinces and 355 county-level administrative regions across China. It is the largest household survey in China specializing in household finance and it also provides critical information for many other aspects of the Chinese household. Compared to the CFPS data used by Cheng (2020) and the CGSS survey used by He et al. (2022), the CHFS data offers a unique advantage both in terms of a larger sample and sub-provincial city-level representativeness.

In this survey, individual happiness is measured through the following question: 'In general, do you feel happy now?'. The answer to this question is classified into five categorical levels: very happy; happy; generally happy; unhappy; and very unhappy. We use a descending order to capture levels of happiness: 5 to represent very happy and 1 for very unhappy. In other words, the higher the score, the happier the respondent is. The same data is also used by Clark et al. (2019) to understand the factors contributing to subjective well-being in China.

The distribution of individual happiness scores is plotted in Fig. 3. A significant portion of the Chinese population expressed that they are satisfied with their current lives, as evidenced by 62.30% of individuals choosing options associated with 'happy and very happy'. Conversely, only approximately 1.07% of individuals characterize their state of life satisfaction as 'very unhappy'. Based on examining trends over the years, there is a noteworthy rise in the proportion of individuals identifying as 'very happy', increasing from 15.37% in 2011 to 22.78% in 2019. Meanwhile, the percentage of individuals indicating that they are 'unhappy' decreased from 2013 to 2019.

[Insert Fig. 3 about here]

In addition to the key dependent variable, namely happiness, we also extract information about other household characteristics from the CHFS survey. These factors are used as control variables in the empirical analysis. Following Zhang et al. (2017) and Methorst (2024), both individual and household characteristics, such as age, gender, household income, etc., are included. We also control for city-level characteristics, such as GDP growth rate, population density, and other environmental factors which could also affect individual happiness (Xie et al., 2023). For example, air-pollution measure such as PM2.5 is compiled based on relevant information from the Atmospheric Composition Analysis Group.[3] Other city-level data is obtained from the China City Statistical Yearbook and local Bureau of Statistics.

[3] https://sites.wustl.edu/acag/datasets/surface-pm2-5/

3.3 Samples and statistics

Various datasets are merged based on the year and city geographic codes. To clean the data before proceeding to the detailed analysis, the following procedures are conducted: First, we exclude samples with age less than 16 years old; second, we remove samples with missing values for key variables. Following these procedures, a total of 235,897 individual-year observations in 126 cities and from 2011 to 2019 are used in our baseline analysis.

Fig. 4 presents a decile bin scatter plot of bird abundance and individual happiness. It shows a positive correlation between bird abundance and individual happiness. The slope of 0.0162 indicates that a 1-unit increase in log of bird abundance index, the mean happiness increases by 0.0162. Thus, higher bird abundance contributes to improving human well-being, warranting further empirical analysis to explain this relationship.

[Insert Fig. 4 about here]

[Insert Table 1 about here]

Table 1 presents the summary statistics for the key variables. Residents generally express higher levels of well-being, reflected in an average happiness score of 3.726. The average log of city bird abundance index is 4.693, and the average bird richness index is 6.871 in this sample. Moreover, the average age of the respondents is 47.824 and exhibits considerable variability amongst the individuals. In terms of education, the average level in the sample is between 3 and 4, indicating that they conclude their education between junior and senior middle school. The male and female respondents are equally distributed, each constituting approximately 50.0% of the full sample. The rural sample accounts for about 32.9% of the total. Economic development across cities varies quite substantially, ranging from -4.700% to 22.650%. Air pollution remains a problem in China, with the maximum level of PM 2.5 reaching 108.512 $\mu g/m^3$.

4. Empirical models

4.1 Baseline regressions

To examine the effects of biodiversity on individual happiness, we construct a linear regression framework as follows:

$$Happiness_{ijt} = \alpha_0 + \alpha_1 Biodiversity_{jt} + \alpha_2 X_{ijt} + \alpha_3 Z_{jt} + \eta_j + \delta_t + \varepsilon_{ijt} \quad (1)$$

where $Happiness_{ijt}$ is the happiness score for individual i in city j at year t. $Biodiversity_{jt}$ is the city-level bird diversity, specifically including the bird abundance index and the bird richness index. X_{ijt} consists of control variables at the individual and household levels. Z_{jt} comprises control variables at the city level. η_j and δ_t represent the sets of city- and year-fixed effects, respectively. These are used to absorb all time-invariant or region-invariant features that may influence individual happiness outcomes. ε_{ijt} is the random error term.

The coefficient, α_1, measures the effect of the city's biodiversity on the happiness of residents. We anticipate the results to be positive, as the preservation of biodiversity is directly linked to the conditions of ecosystems. Well-preserved ecosystems contribute to psychological attitudes, thereby positively influencing the well-being of individuals.

Considering that the happiness indicator is a 1-5 ranked variable, we further follow Burgess and Donaldson (2010) and Carman (2013), employing an ordered logit model to re-estimate Eq. (1). Its marginal coefficients indicate the probability of changes in happiness levels when biodiversity is increased by one unit.

4.2 Additional analysis: The role of natural reserves

In addition to the baseline framework, we also aim to further explore the impacts of biodiversity improvements on human well-being. To do so, we use the new establishment of natural reserves as an experiment to further analyze the role of biodiversity conservation. As of 2019, China has established over 2700 nature reserves at various levels. The nature reserves are vital components of China's efforts to protect ecosystems and proved to be an effective measure to conserve biodiversity (Chen et al., 2023). On the one hand, the newly established nature reserves can enhance habitat quality while reducing human activities in the protected areas, both contributing to the improvement of biodiversity. On the other hand, the decision to establish new nature reserves is independent from individual preferences, which is exogenous to the model setup here and can thus be used to confirm the relationship found in the baseline regressions.

Following the arguments above, we can set up a staggered DID method to compare the difference in residents' happiness between cities with an increase in nature reserves and other cities without an increase in nature reserve, thus allowing us to infer a causal link between biodiversity conservation and human well-beings. The specific regression model is established as follows:

$$Happiness_{ijt} = \beta_0 + \beta_1 Treat_{jt} + \beta_2 X_{ijt} + \beta_3 Z_{jt} + \lambda_i + \eta_j + \delta_t + \varepsilon_{ijt} \quad (2)$$

where $Happiness_{ijt}$ is the happiness outcome for individual i in city j at year t. $Treat_{jt}$ is an indicator variable, equaling one for the years when new nature reserves are established in the city and zero otherwise. The coefficient β_1 is the key, conveying the difference in individual happiness between the treated and non-treated samples. X_{ijt} and Z_{jt} include the total number of nature reserves in the city, along with the set of individual and city control variables mentioned previously. Additionally, λ_i, η_j, and δ_t represent the sets of individual-fixed, city-fixed, and year-fixed effects, respectively.

Considering that the staggered DID method is susceptible to bias arising from heterogeneity over time and between sample groups, we also employ the event study DID model to conduct parallel trend tests. The model integrates three over- and lagged periods before and after the emergence of new nature reserves and is established as follows:

$$Happiness_{ijt} = \alpha + \sum_{k=-3}^{2} \beta_k Treat_{jt+k} + \gamma X_{ijt} + \theta Z_{jt} + \lambda_i + \eta_j + \delta_t + \varepsilon_{ijt} \quad (3)$$

where the indicator variable $Treat_{jt+k}$ denotes the relative time during which the increase in nature reserves occurred in city j. For example, $Treated_{jt-2}$ refers to the two years prior to the increase in nature reserves. The reference group is the year before the increase in nature reserves $(k = -1)$.

5. Results and discussions

5.1 Baseline regressions

The first question we explore is whether biodiversity increases levels of human well-being, as measured through individually self-reported happiness. We estimate Eq. (1) using linear and ordered logit models for cross-validation. The results are presented in Table 2.

[Insert Table 2 about here]

The table presents a set of consistent results suggesting that bird diversity significantly increases happiness, even after accounting for individual economic and social factors. The coefficients for age and education level are both significantly positive, implying that people are more likely to be satisfied with their lives as age and education levels increase. Males are relatively less happy compared to females. When comparing urban and rural residents, we note that rural residents are likely to be happier. This may be related to the pressure of their surrounding living environments. In terms of family characteristics, larger family size and more dispersed family resources correlate with lower happiness levels. Total household income exerts a positive and significant effect on individual happiness. In other words, people tend to be happier in richer families.

Regarding the city characteristics, GDP growth positively influences individual happiness, while population size has a negative effect. This is intuitive in the sense that a large and crowded city tends to be suffused with more tension and pressure, leading to lower levels of life satisfaction. Notably, the PM2.5 coefficient is 0.002, suggesting that an increase in PM2.5 contributes to higher individual happiness. This result is consistent with Li et al. (2019), indicating a non-linear relationship between happiness and environmental pollution, with individual happiness remaining positive at lower pollution concentrations.

As the measure of happiness in an ordered discrete variable, we use the ordered logit model to understand the impacts. In addition to the estimated positive effect, we are also interested in the marginal effects, which are reported in Table 3. The marginal effects of biodiversity on different happiness groups are indicated in the table. The coefficients in columns (1)-(3) are significant and negative, indicating that an increase in biodiversity reduces the probability of people falling into these categories. These groups encompass people who are very unhappy (1), unhappy (2), and generally happy (3), whereas the last two groups include people who are happy (4) and very happy (5). The results indicate that improved biodiversity makes people less likely to be unhappy and more likely to be happy. For example, one standard deviation more in log of city bird abundance index

(1.050) can increase the probability of being happy and very happy by 0.315%.

[Insert Table 3 about here]

Notably, the coefficients are generally small, though they are statistically significant at the 1% level. In general, the determinants of happiness are complicated, and the psychological attitude of an individual tends to be affected by many factors. Improving biodiversity alone may not necessarily yield fundamental changes. Nonetheless, relative to some previous studies with mixed results (e.g. Cheng, 2020; He et al., 2022), we find consistent and significant positive effects of biodiversity on human well-being. Moreover, if we interpret the results in a different manner (e.g. improving biodiversity by one standard deviation can lead to 0.315% of people being in the top two happiness groups), then the impacts may not be small.

5.2 Exploring the relationships within sub-groups

To further explore the effects of biodiversity on happiness across different characteristic groups, we divide our samples based on the following: i) age groups (16 to 45 years classified as young, 46 to 64 years as middle-aged, and 65 years and above as old); ii) income groups (low-income, middle-income, and high-income households, determined by quartiles of annual household income); iii) the economic development level of the city (classified into developed and less-developed cities, based on the median per capita GDP of the city); and iv) status as an industrial city or not (based on the median share of secondary industry). The results are presented in Table 4.

[Insert Table 4 about here]

Improvements in biodiversity are found to have heterogenous effects across these sub-groups. First, the impact on happiness varies significantly across age groups. The positive significant result for the older group indicates that improving biodiversity yields the greatest benefits for people over 65 years old. The positive effect also applies to the young group but not to the middle-aged group. In literature, the U-shaped relationship between happiness and age is a well-established phenomenon (e.g. Frijters and Beatton, 2012), thus our findings are consistent. People in this age group tend to receive much stronger pressure from their family and at work. Relative to other groups, in addition, these people may need to devote more attention to economic conditions rather than pursuing leisure, thus not necessarily benefiting from the improving biodiversity, especially when the improvement comes with costs. The strongest effect found for elder people also has important meanings regarding China. As the country is now becoming an elder society, the value of biodiversity has increased.

For households in different income groups, biodiversity is more influential for high-income and middle-income households, with no significant difference in its effect on low-income households. The last two columns of Table 4 focus on city characteristics. Regarding economic performance, the significant coefficient for the interaction term indicates that biodiversity has a more pronounced positive impact on happiness in developed cities. This suggests that as cities become more economically prosperous, the benefits of biodiversity in enhancing human well-being become increasingly evident. In contrast, in industrial cities, there is a weaker relationship between biodiversity and happiness.

5.3 Testing possible channels

In this section, we explore how biodiversity affects individual happiness, focusing specifically on health-related aspects. While multiple pathways may exist, we emphasize two key channels: first, a stable ecological environment directly influences physical health; second, green spaces encourage physical activity, both are important for making people happy.

Firstly, the protection of biodiversity is closely linked to the stability of ecosystems (Naeem and Li, 1997), which play a crucial role in disease prevention and the maintenance of air and water quality, positively impacting physical health (Roslund et al., 2020). Physical health, in turn, contributes to self-reported individual happiness (Hudson et al., 2019). To investigate this pathway, we use the log of household per capita healthcare expenditure from the CHFS to capture individual health conditions. Since this data has been available since 2015, we analyze survey data from 2015 to 2019, along with relevant biodiversity information.

A two-step approach is used to identify the channel effects, and the results are presented in Table 5. The findings show that improvements in bird diversity significantly reduce healthcare expenditures. Additionally, the second-step regression results show a statistically significant negative correlation between healthcare expenditures and happiness. This effectively demonstrates the existence of the first channel: in regions with higher biodiversity, individuals typically enjoy better physical health, which contributes to increased human well-being.

[Insert Tables 5-6 about here]

Secondly, at the city level, rich biodiversity is often associated with the availability of natural spaces (Loss et al., 2009), such as high vegetation coverage and water bodies (Beninde et al., 2015), which provide areas for outdoor activities. Exposure to natural environments can increase the frequency of physical activity, positively influencing health and happiness (Huang et al., 2023). To examine this channel, we use data from the China Health and Retirement Longitudinal Study (CHARLS), which represents individuals aged 45 and above in China. While obtaining relevant information on outdoor activities can be challenging, we employ a broad range of activities as a substitute. In CHARLS, activities are categorized into three types: vigorous activities (e.g., aerobic exercise and fast cycling), moderate-intensity activities (e.g., Tai Chi and brisk walking), and mild activities (e.g., walking). Respondents are asked if they engage in at least 10 minutes of these activities per week to capture their activity types. Self-reported health status is assessed using a five-point scale, while self-rated well-being is measured through life satisfaction (as CHARLS does not include happiness questions). Additionally, we validate the relationship between health and happiness using data from the CHFS.

We analyze CHARLS data in waves of survey conducted in 2011, 2013, 2015, and 2018. Since the three types of activities are binary (0-1) variables, we employ both the logit and linear regression models for the analysis. The results, presented in Table 6, reveal that increased bird abundance significantly enhances the frequency of vigorous and moderate physical activities among the elderly. This suggests that better biological environments encourage individuals to engage in physical activities, thereby improving their physical health. Furthermore, participation in activities of varying intensities significantly enhances individual health. Healthy individuals show positive effects on life satisfaction and overall well-being. These findings further underscore the importance of biodiversity in promoting physical activity and enhancing individual health and happiness.

5.4 The impacts of alternative measures

In this section, we use the bird richness index to test the robustness of the baseline results. Continuing from Section 5.1, we also estimate Eq. (1) using both linear regression models and ordered logit models, with the results presented in Tables 7 and 8.

[Insert Tables 7-8 about here]

In Table 7, the coefficients for the bird richness index consistently indicate that bird diversity significantly enhances happiness, even after controlling for individual, family, and city factors. Meanwhile, the results from the ordered logit model (Table 8) show that an increase in biodiversity significantly reduces the likelihood of individuals falling into the categories of very unhappy (1), unhappy (2), and generally happy (3). Conversely, it increases the likelihood of individuals being classified as happy (4) or very happy (5). These results align seamlessly with our main empirical findings, underscoring the stable and important role of bird diversity in enhancing happiness.

5.5 The impacts of newly established natural reserves (DID)

This section reports the empirical results for the staggered DID regression to examine the impacts of newly established nature reserves on happiness. Before examining the regression results, we plot the cities with newly established nature reserves against bird abundance index in Fig. 5. Here, t=0 refers to the year when new nature reserves were established. The decline in bird species is alleviated after the additional nature reserved, confirming our hypothesis that new nature reserves can improve biodiversity. In this figure, 77 cities have new nature reserves and are considered the treatment group. However, in the regression analysis, after merging with the household survey data, only 48 cities with new nature reserves are left and are used in the actual regressions.

[Insert Fig. 5 about here]

[Insert Table 9 about here]

Table 9 reports the results of increased nature reserves on happiness by estimating Eq. (2). Columns (1)-(3) progressively control for individual, household, and city factors, and the results remain consistent and significant. The coefficient of $Treat$ is 0.158 and is statistically significant at the 1% level, suggesting that an increase in nature reserves positively contributes to individual happiness relative to cities without new nature reserves. This result confirms that biodiversity contributes to increased individual well-being.

We further employ the event study DID to illustrate the effects of the years before and after the change in nature reserves on individual happiness. The results are presented in Fig. 6. Two and three years before the increase in nature reserves, individual happiness is not associated with any significant responses. However, happiness increased significantly in the period in which the increase in nature reserves occurred and remained significantly greater than zero in subsequent years. Thus, an increase in nature reserves significantly enhances individual happiness.

[Insert Figs. 6-7 about here]

To further confirm the validity of the DID model, we perform a placebo test by randomly selecting cities in the sample and running the regressions over 500 times. The results are plotted in Fig. 7, and the estimated coefficients of the randomly generated treatment groups are centered around zero, differing significantly from the true coefficient of 0.158.

6. Conclusions

Biodiversity loss has been considered one of the major threats to sustainable development and has garnered attention worldwide. Countries such as China have started to actively engage in biodiversity conservation. These activities are, however, costly and demand strong policy support. While the long-term benefits of biodiversity cannot be denied, it is important for policymakers to note the value of enhanced biodiversity. Meanwhile, making the public aware of the value of a more diversified ecosystem is equally critical. This paper therefore aims to add evidence to the thriving literature by empirically studying the value of biodiversity to promote non-economic benefits, namely the happiness of the Chinese people.

We recognize the multidimensional nature of the measurement of biodiversity but also realize that a sophisticated measure is not the key for understanding its socio-economic impacts. Thus, following the existing literature, we opt to measure the popular bird species diversity (the bird abundance index and the bird multiplicity index) in Chinese cities and use it as a proxy for biodiversity in the following empirical analysis. This index has been declining over the sample period, revealing the severe challenges China faces in biodiversity conservation. To link city-level biodiversity with individuals, we use the CHFS survey data to extract information about happiness, health status, and other demographic characteristics.

Regressions using these data indicate a consistent and significant positive relationship between biodiversity and happiness, corroborating our initial hypothesis about the value of biodiversity. Furthermore, the biodiversity-happiness relationship is found to exhibit clear heterogeneity across different groups. Specifically, we study three age groups and two income groups at the household level and then investigate two city-specific groups. The value of biodiversity is more significant for elderly people, high-income households, developed and non-industrial cities. Moreover, we explore the possible channels with a specific focus on the health effects, demonstrating that biodiversity can improve health status or reduce medical expenses and thus contributing to significantly higher levels of happiness.

To provide further confirmation and avoid endogeneity issues in the baseline regressions, we conduct a quasi-natural experiment regarding the newly established nature reserves to reinvestigate this issue in a staggered DID setup. Nature reserves play an important role in biodiversity conservation, and cities enjoy improved biodiversity when a new nature reserve is established in that city. The regression results also demonstrate consistent and statistically significant results, thus reinforcing the biodiversity–happiness relationship.

Overall, our paper presents a strong set of empirical results for a large developing country, China, to support the non-economic values of improving biodiversity. The policy implications are threefold: First, despite the cost of conservation, investing in natural capital has both long-term value and short-term value. This value is not only economically relevant but also involves improvements in social welfare. Second, policymakers must realize the heterogeneity in the biodiversity–happiness relationship. As the aging of Chinese society progresses further, improving biodiversity has even more profound meaning and may potentially lead to economic benefits indirectly through reductions in medical expenses. Third, establishing nature reserves should be further encouraged. In addition to enhancing biodiversity, this can also increase social welfare.

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Tables and figures

Table 1 Summary statistics for the variables

Variables	Obs	Mean	S.D.	Min	Max
Key variables					
Happiness	235,897	3.726	0.848	1	5
Abundance (log of bird abundance)	235,897	4.693	1.050	0.693	7.971
Richness	235,897	6.871	7.416	0.338	70.000
Individual and Household Characteristics					
Age	235,897	47.824	17.634	16	117
Gender (male = 1)	235,897	0.500	0.500	0	1
Education	235,897	3.571	1.789	1	9
Married (married = 1)	235,897	0.782	0.413	0	1
Rural (rural resident = 1)	235,897	0.329	0.470	0	1
Familysize	235,897	3.922	1.781	1	19
Income (log of household income)	235,897	10.615	1.417	0.161	16.311
City Characteristics					
Growth (GDP growth rate %)	235,897	8.641	3.423	-4.700	22.650
Population (log of population)	235,897	6.392	0.691	4.072	8.137
Industry (share of secondary industry, %)	235,897	41.978	10.734	16.160	70.600
PM2.5 (unit: $\mu g/m^3$)	235,897	44.281	15.551	13.589	108.512

Table 2 Effects of bird abundance on happiness

	(1)	(2)	(3)	(4)	(5)
	Linear Model	Linear Model	Linear Model	Linear Model	Ologit Model
	Happiness	Happiness	Happiness	Happiness	Happiness
Abundance	0.011***	0.009***	0.010***	0.007***	0.012**
	(4.43)	(3.46)	(3.73)	(2.80)	(2.04)
Age		0.003***		0.003***	0.007***
		(25.49)		(25.51)	(25.95)
Gender		-0.022***		-0.022***	-0.045***
		(-6.39)		(-6.41)	(-5.84)
Education		0.023***		0.023***	0.047***
		(18.91)		(19.11)	(17.04)
Married		0.100***		0.099***	0.205***
		(21.96)		(21.92)	(20.19)
Rural		0.015***		0.015***	0.041***
		(3.53)		(3.48)	(4.22)
Familysize		-0.005***		-0.005***	-0.009***
		(-4.57)		(-4.43)	(-3.48)
Income		0.062***		0.062***	0.132***
		(42.90)		(42.87)	(40.83)
Growth			0.011***	0.008***	0.020***
			(10.11)	(7.73)	(8.24)
Population			-0.303***	-0.416***	-0.096***
			(-7.03)	(-9.72)	(-9.68)
Industry			0.001	0.001	0.001
			(1.14)	(1.03)	(0.83)
PM2.5			0.002***	0.002***	0.005***
			(3.69)	(3.79)	(4.31)
_cons	3.672***	2.746***	5.397***	5.214***	-
	(302.22)	(131.77)	(19.91)	(19.44)	
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	235,897	235,897	235,897	235,897	235,897

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively. Ologit model refers to the ordered logit model.

Table 3 Marginal effects of bird abundance on happiness based on the Ologit Model

	(1) Happiness=1	(2) Happiness=2	(3) Happiness=3	(4) Happiness=4	(5) Happiness=5
Abundance	-0.0001***	-0.0006***	-0.002***	0.001***	0.002***
	(-2.03)	(-2.04)	(-2.04)	(2.04)	(2.04)
Individual Control	Yes	Yes	Yes	Yes	Yes
Household Control	Yes	Yes	Yes	Yes	Yes
City Control	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	235,897	235,897	235,897	235,897	235,897

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

Table 4 Effects of bird abundance on happiness in different groups

	(1)	(2)	(3)	(4)
	Happiness	Happiness	Happiness	Happiness
Abundance	0.006**	-0.002	0.006**	0.015***
	(2.21)	(-0.74)	(2.26)	(5.36)
Abundance*Mid-aged people	-0.008***			
	(-5.96)			
Abundance*Old people	0.022***			
	(10.60)			
Abundance*Middle-Income		0.009***		
		(7.50)		
Abundance*High-Income		0.027***		
		(17.52)		
Abundance*Developed city			0.003*	
			(1.81)	
Abundance*Industrial city				-0.012***
				(-7.36)
Individual Control	Yes	Yes	Yes	Yes
Household Control	Yes	Yes	Yes	Yes
City Control	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	274,121	274,121	274,121	274,121

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

Table 5 Effects of bird abundance on health care

	(1) Mediator Health expenditure	(2) Dependent variable Happiness	(3) Mediator Health expenditure	(4) Dependent variable Happiness
Abundance	-0.018***	0.004*	-0.037***	-0.005
	(-2.71)	(1.71)	(-3.04)	(-1.19)
Health expenditure		-0.017***		-0.020***
		(-21.77)		(-24.19)
Individual Control	Yes	Yes	Yes	Yes
Household Control	Yes	Yes	Yes	Yes
City Control	Yes	Yes	Yes	Yes
City FE	No	No	Yes	Yes
Year FE	No	No	Yes	Yes
N	157,350	157,350	157,350	157,350

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

Table 6 Effects of bird abundance on Health

	(1)	(2)	(3)	(4)	(5)	(6)
	Mediator	Mediator	Mediator	Dependent variable	Dependent variable	Dependent variable
	Vigorous activity	Moderate activity	Mild activity	Health	Life satisfaction	Happiness (CHFS)
Abundance	0.075***	0.061***	0.017	-0.004	0.020***	0.007**
	(3.13)	(2.78)	(0.59)	(-0.43)	(2.60)	(2.38)
Vigorous activity				0.079***		
				(4.44)		
Moderate activity				0.083***		
				(5.14)		
Mild activity				0.086***		
				(3.88)		
Health					0.197***	0.196***
					(28.31)	(88.08)
Individual Control	Yes	Yes	Yes	Yes	Yes	Yes
Household Control	Yes	Yes	Yes	Yes	Yes	Yes
City Control	Yes	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	14,839	14,839	14,839	14,839	14,839	201,253

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

Table 7 Effects of bird richness on happiness

	(1)	(2)	(3)	(4)	(5)
	Linear Model	Linear Model	Linear Model	Linear Model	Ologit Model
	Happiness	Happiness	Happiness	Happiness	Happiness
Richness	0.003***	0.002***	0.003***	0.002***	0.002***
	(6.93)	(4.38)	(7.04)	(4.91)	(4.91)
Individual Control	No	Yes	No	Yes	Yes
Household Control	No	Yes	No	Yes	Yes
City Control	No	No	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	235,897	235,897	235,897		

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

Table 8 Marginal effects of bird richness on happiness based on the Ologit Model

	(1)	(2)	(3)	(4)	(5)
	Happiness=1	Happiness=2	Happiness=3	Happiness=4	Happiness=5
Richness	-0.00004***	-0.0002***	-0.0007***	0.0003***	0.0006***
	(-4.56)	(-4.57)	(-4.58)	(4.58)	(4.58)
Individual Control	Yes	Yes	Yes	Yes	Yes
Household Control	Yes	Yes	Yes	Yes	Yes
City Control	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	235,897	235,897	235,897	235,897	235,897

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

Table 9 Effects of increased nature reserves on happiness

	(1) Happiness	(2) Happiness	(3) Happiness
Treat	0.157***	0.159***	0.158***
	(4.74)	(4.80)	(4.78)
Individual Control	No	No	Yes
Household Control	No	Yes	Yes
City Control	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	119,989	119,989	119,989

Notes: *t* statistics are given in brackets. ***, ** and * denote a significance of 1%, 5% and 10%, respectively.

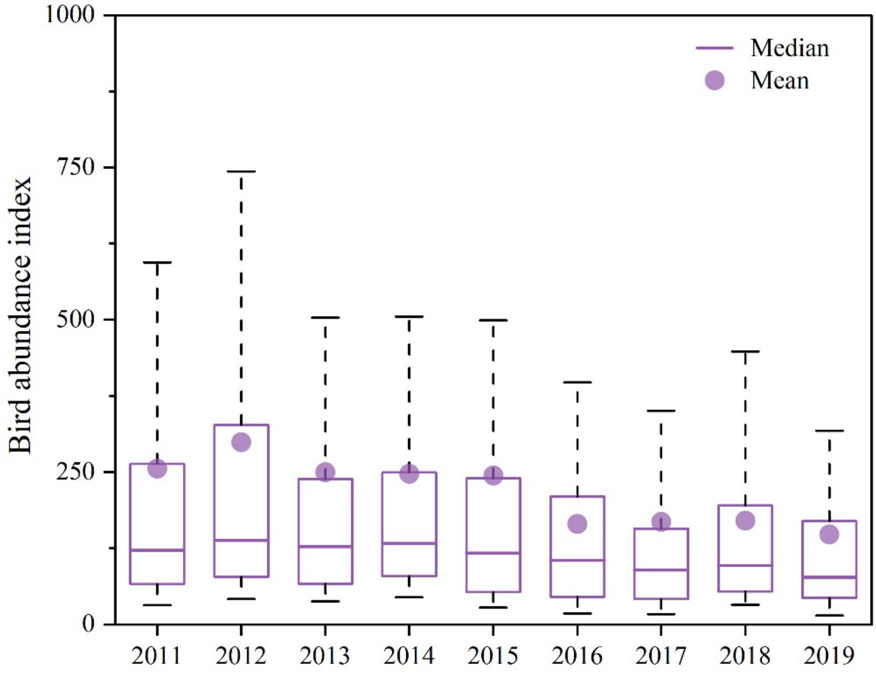

Fig. 1 Bird abundance index in China: 2011-2019

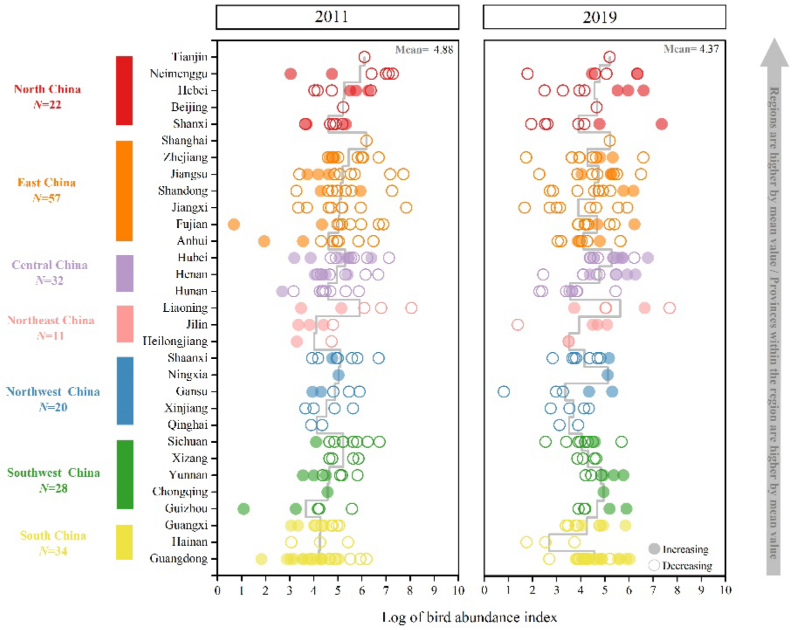

Fig. 2 Bird abundance index distribution of Chinese cities: 2011 and 2019

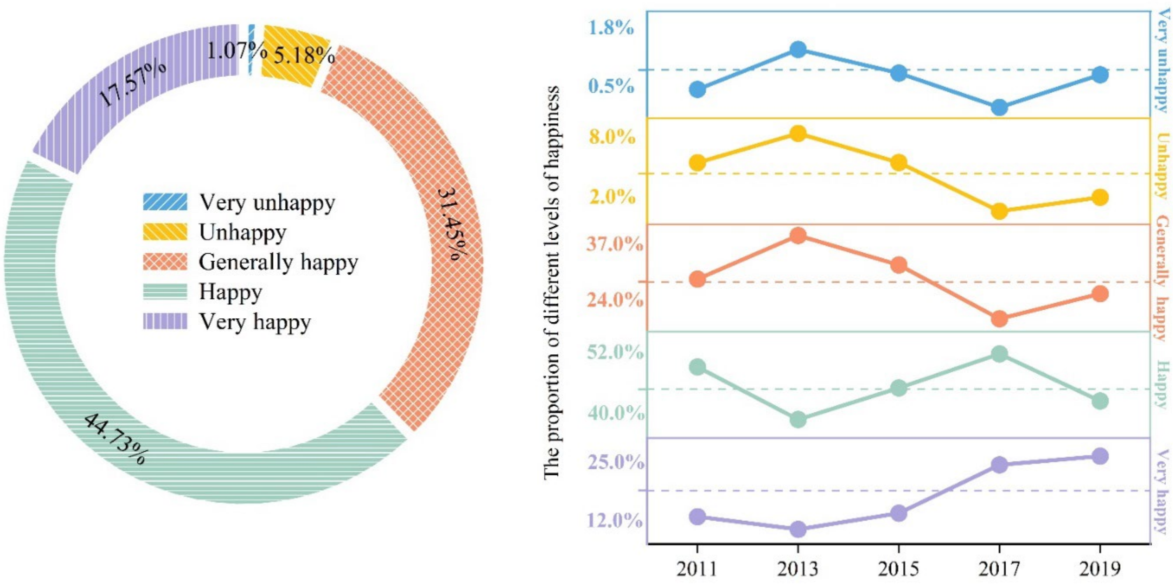

Fig. 3 Distribution of individual happiness scores overall (left) and by year (right), 2011-2019

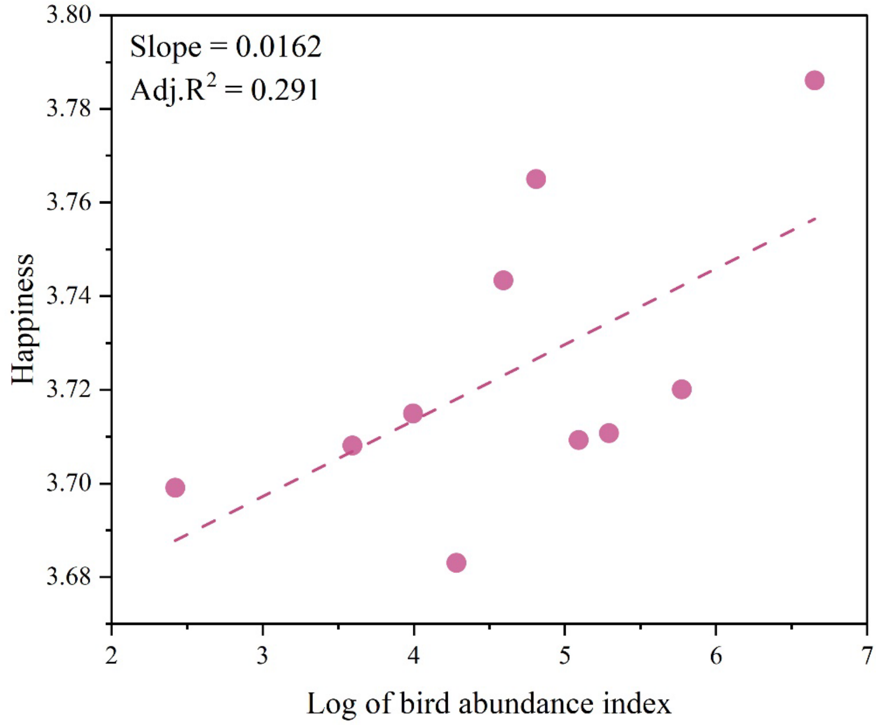

Fig. 4 Bin scatter plot of bird abundance index and happiness

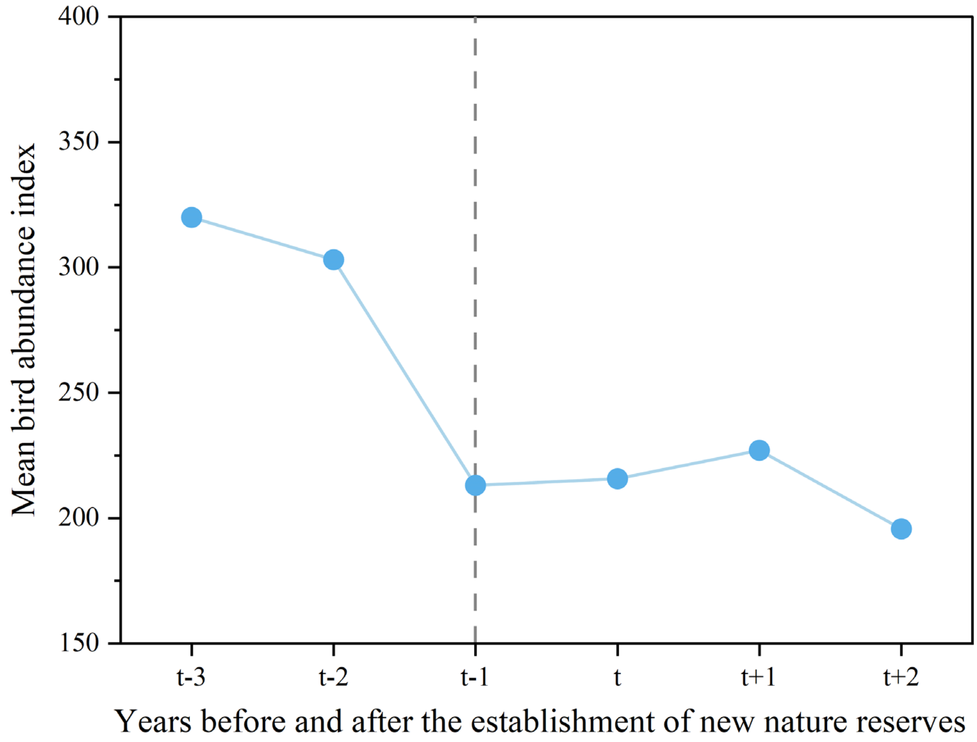

Fig. 5 Bird abundance index and the establishment of new nature reserves

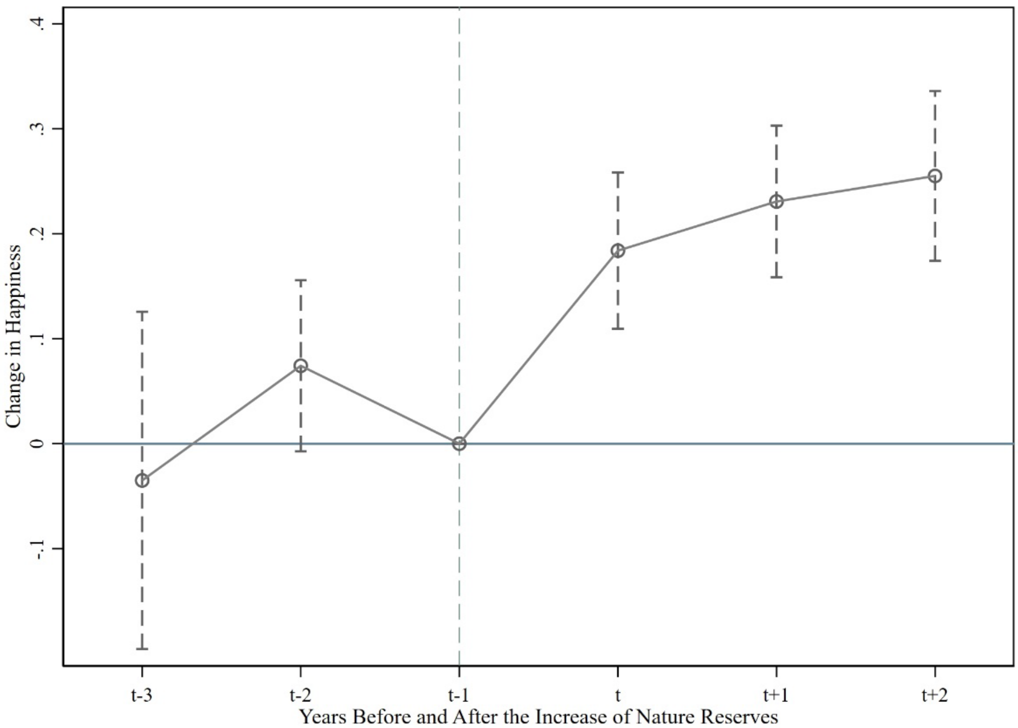

Fig. 6 Effects of newly established natural reserves on happiness

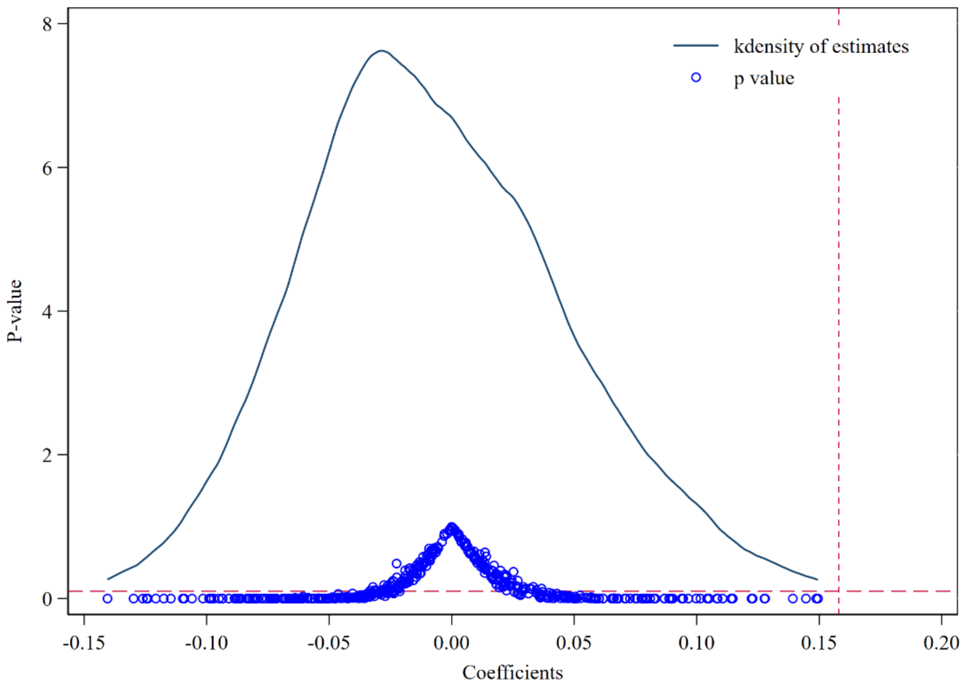

Fig. 7 Distribution of estimated coefficients for the 'pseudo-treatment group'

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