Economic Development and Conservation Impacts of China's Nature Reserves

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Audrey T. Cheng[§], Katharine R.E. Sims[‡*], and Yuanyuan Yi[§]

[§] audrey.cheng27@gmail.com, Harvard University and Amherst College, United States
[‡] ksims@amherst.edu, Department of Economics, Amherst College, United States
[§] yyyi@nsd.pku.edu.cn, China Center for Economic Research, National School of Development, Peking University, China

Abstract

Protected areas are a dominant but contentious instrument of conservation policy. Restrictions on resource extraction and land use constrain livelihoods but may also support alternate pathways to development through sustainable use, tourism, and landscape amenities. We investigate the economic development and environmental impacts of China's Nature Reserves using county-level panel data between 1980 and 2010. We find small positive impacts on an aggregate household development index and that Nature Reserves maintained natural land cover within their boundaries. We also find employment shifts from resource-extractive to service-based activity, but an overall negative impact on reported employment. Household development gains and shifts towards service-based employment were greater closer to locations that were already more developed and had higher baseline assets. These results indicate both the promise of protected areas as a sustainable development strategy and the need for institutional mechanisms to ensure that local benefits and employment opportunities are broadly distributed.

Keywords: Protected Areas; Economic Development; Nature Reserves; Sustainable Development; China; Land Conservation; Parks; Ecotourism

JEL: Q01, Q56, Q57, Q24

1. Introduction

Protected areas are a key tool for conservation policy, but they must be implemented with extra care where local incomes are dependent on natural resource use. Although the positive externalities of land protection are substantial at the national and international level, opportunity costs may be high for local people. The relationships between protected areas and local communities are characterized by both symbiosis and tension (e.g. Adams et al. 2004, Ferraro and Pressey 2015, Oldekop et al. 2016). Restrictions on agricultural development and natural resource extraction in protected areas may threaten rural livelihoods (e.g. Xu et al. 2006a, Brockington et al. 2006, Zafra-Calvo 2017, Paudel 2018). On the other hand, protected areas may support alternate pathways to economic development by creating non-extractive employment opportunities such as eco-tourism and by supporting enhanced ecosystem services, increased sustainable use, or improved landscape amenities (Dixon and Sherman 1990, Sims 2010, Andam et al. 2010, Ferraro and Hanauer 2014, Robalino and Villalobos 2015, Naidoo et al. 2019). Given these potential tensions and opportunities, empirical research on the impacts of protected areas is important in order to understand the conditions for possible win-win environment and development strategies. In this paper, we assess how protected areas in China have affected household development, employment, and land-cover change.

China's protected area system provides a crucial test of the compatibility between conservation and economic development. China is the third largest country in terms of land area, and is home to a highly diverse set of ecoregions and geographical features (Ren et al. 2015, Cao et al. 2015). It has also, for the past half-century, confronted continued threats to ecological integrity from deforestation, habitat loss, and industrial pollution (Delang and Yuan 2016). Recently, the Chinese government has formally recognized nature as one of the country's most precious assets, pursuing a strategy of "ecological civilization" that puts conservation on par with economic development in a push for national sustainable development, and emphasizing protected areas as a crucial part of this strategy (Cao et al. 2015, Goron 2018). A network of over two thousand protected areas, mainly designated as Nature Reserves, spans the entire mainland, with goals of conserving the natural and cultural heritage of China (Xu et al. 2012, Ren et al. 2015, Cao et al. 2015). These areas restrict development and resource extraction but allow limited human use and often actively promote visitation as a means of development (Cao et al. 2015). Indeed, eco-tourism has been growing rapidly (Wang et al. 2012) and has been established in more than 98% of reserve areas (Liu et al. 2013).

Previous case-based research on China's Nature Reserves has found mixed results for economic development (Chen et al. 2005, Su and Wall 2012, Wang et al. 2012, Duan and Wen 2017, Ma et al. 2019a). These prior studies have generally focused on a small number of prominent areas and do not identify causal effects, assess heterogeneity in impacts, or simultaneously evaluate the interplay between conservation and development. Larger scale studies of the local economic impacts of protected areas with rigorous evaluation designs exist for other countries including Nepal, Mexico, Costa Rica, Thailand, Peru, and the U.S., but do not include China (Sims 2010, Ferraro and Hanauer 2014, Robalino and Villalobos 2015, Miranda et al. 2016, Sims and Alix-Garcia 2017, Sims et al. 2019, Howlader and Ando 2020, Walls et al. 2020, Ferris and Frank 2021). Many of these studies indicate net positive economic impacts of protected areas, although several have found no evidence for livelihood gains and that protected areas have exacerbated inequality (Sims 2023). Taken together, the context-specific results of prior studies highlight the need for country-level assessments. Protected area impacts have depended on factors including environmental pressures, alternate economic opportunities, and institutional structure (e.g. Ferraro et al. 2011, Pfaff and Robalino 2012, Sills and Jones 2018). China is a large and unique country, offering an important addition to the global evidence base of park impacts. In addition, results from a national-scale, retrospective evaluation in China are especially relevant at this time, as the government is in process of planning an upgrade of its Nature Reserves to a system of National Parks (Ma et al. 2019b, Larson 2019).

To evaluate China's protected areas, we use a quasi-experimental panel regression methodology with census and geographic data from 1980/82, 1990, 2000, and 2010. This encapsulates the time period in which the majority of Nature Reserves were established and there was rapid and dispersed growth in area protected. Our primary outcome of interest is a household development index ("HDI") based on indicators of education, health and material assets, and aggregated to the county level. We also estimate impacts on total employment and the share of employment in each sector for these county units. In addition, we evaluate land cover change impacts for both county and protected area-level units to assess whether Nature Reserves may have simply been "paper parks" or whether they were effective in limiting land-cover change. Finally, we estimate heterogeneity in impacts to understand how the location of reserves may matter for their ability to deliver both ecological and economic improvements. We outline potential channels for positive externalities from protected areas and indicate whether our evidence is consistent with these channels.

Our research provides a substantial advance relative to prior work on both socioeconomic and land cover change impacts in China by comprehensively analyzing protected area impacts for the country as a whole and by using panel data to estimate impacts from variation over time in Nature Reserve establishment. Our work also advances the previous literature by examining land-cover outcomes at a national scale. Few prior studies have assessed land cover impacts of Nature Reserves at a large scale in China. The exception to this is Ren et al. (2015), which estimated that National Nature Reserves prevented forest loss between 2000 and 2010, using a matching approach. Our results complement and extend this analysis by estimating the impacts of Nature Reserves over the full timespan from 1980 to 2010, using changes in reserve establishment to estimate impacts, and comparing heterogeneity in impacts across land cover and socioeconomic outcomes.

We find small positive nationwide impacts of Nature Reserves on the household development index, as well as employment shifts from resource-intensive industries towards service-based activity. Land cover changes during our study period were limited in magnitude both inside and outside of protected areas. Our estimates indicate that protected areas resulted in more forest cover and less human settlement within protected areas, but these results are not statistically significant. We find evidence for stronger increases in household development for areas likely closer to tourists and markets, indicating the potential for protected areas to contribute to sustainable development. However, we also find that Nature Reserves have decreased formal employment on average, and by more in the same types of locations where household development and tertiary sector employment tended to increase. Taken together, these results may indicate positive development channels of protected areas, including a shift towards household investment in educational attainment rather than labor force participation, or increased informal employment that improves livelihoods but is not reflected in employment statistics. On the other hand, they could also indicate that job creation from tourism due to parks has not kept up with the rapid growth from industrialization in similar areas without land protection. Finally, the substantial heterogeneity in impacts that we find suggests a need for policymakers to continue focusing attention on whether all local people are receiving benefits and opportunities from protected areas. Our results highlight the importance of promoting diverse regional economies and landscape-scale planning in order to ensure that protected areas are embedded in areas with multiple economic opportunities.

2. Background

2.1 China's Nature Reserves and designation process

By 2017, China had 2,740 Nature Reserves covering 18% of land area (Wang 2017; Yang and Cao, 2017). In 2010, 46% of the population lived in counties with at least 1% protected, indicating substantial exposure of people to these Nature Reserve areas (also see Appendix Figure A1 which illustrates population density and Nature Reserve locations). Our analysis focuses on reserves established prior to 2010 in order to match them with available census data from 1982, 1990, 2000 and 2010.

Nature Reserves were established starting in the 1950's – right after the foundation of the New China in 1949. Dinghu Mountain in Guangdong Province was the first, with 19 additional reserves following by 1966 (Cao et al. 2015). The growth of protected areas in our study period is visualized in Figure 1.

The selection and designation procedures for Nature Reserves were driven primarily by protecting areas of high ecological and natural resource importance, with increasing emphasis on additional multiuse goals and local stakeholders over time. Before 1991, the establishment of Nature Reserves was highly centralized and focused on biological and habitat conservation as well as valuable natural resources (Jim and Xu, 2004). Conservation needs were determined primarily by the central government, according to national draft plans and motivated by observed losses of biodiversity and degradation of local habitats. The goals of Nature Reserves were aimed mainly at reducing logging and hunting in high-value natural areas (Jim and Xu, 2004). By 1978, 41 reserves were proposed by scientists based on biological field surveys with a primary goal of protecting rare flora and fauna in core land systems (Xue and Jiang 1994).

After 1991, the designation process reflected China's commitment to expand its Nature Reserve system with a broader set of goals and with more input from provincial and county governments (Global Environmental Facility 1995; Crooks et al. 2001). In this phase, Nature Reserves were expanded to include multiple categories with additional purposes including geological or paleontological heritage and marine and coastal ecosystems. The procedures for Nature Reserve designation were standardized and provincial and county governments began to play a stronger role in reserve selection and management, taking local needs into account (Jim and Xu, 2004). These procedures encouraged consultation with key local stakeholders and goals of settling land disputes before designating new protected areas. In this time period, more Nature Reserve designation and management was devolved to provincial and county governments.[1] The decades that followed saw rapid increases in Nature Reserves: by 1990, there were approximately 600 reserves, whereas by 2000 there were approximately 1,200 reserves covering 10,000 square hectares (Cao et al. 2015).

Nature Reserves have continued to play an important role in the most recent time period as well. In 2007, China's General Secretary Hu Jintao proposed ecological civilization as a guiding principle for continued development (Delang and Wang 2013) and marked the central government's augmented efforts on sustainable development. By the end of 2012, more than

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[1] The *Application, Assessment and Ratification Method for Protected Areas Seeking a National Rank and the Principle for Categories and Grades of Nature Reserves*, adopted by the central government in 1991, and the three-stage procedure succinctly incorporated in the *Protected Areas Ordinance*, enacted in 1994, cover Nature Reserves designated at all levels of government. These are the official guides for local governments' statutory designation for Nature Reserves, with detailed instructions for site identification and selection, information collection and document preparation, assessment and ratification (Jim and Xu, 2004). The site identification and selection should also accord with the *National Principles for Categories and Grades for Protected Areas*, the *Protected Areas Regional Demarcation Scheme* (initially endorsed in 1984), and the *Planning Framework for Protected Areas Development in China 1996-2010* (State Council Committee for Environmental Protection 1997). The designation of Nature Reserves since 1991 has considered multiple goals of ecosystem protection and biodiversity conservation: 1) A qualifying site should contain either a representative sample of a major ecosystem type (e.g. tropical mangrove or alpine grassland) that deserves protection, or an endangered species and its habitat, or geological relicts which refer to the key geological features with high scientific, heritage and landscape values, including four major types: tectonic, fossil, landscape and hazard; 2) Sites containing coastal, marine and grassland ecosystems, and geological relicts, should be given a high priority.

2,000 Nature Reserves were established, covering 149.8 million hectares, or 14.94% of the national territory (Cao et al. 2015). In 2019, the government began a new process of creating a system of National Parks (Larson 2019). Chinese officials hired scientists and policymakers from around the world, visited parks, and sought input from international development and conservation organizations to design future parks, which would build on and expand the Nature Reserves system.

Nature Reserves are divided into multiple administrative classes: national-level and provincial, municipal and county-level reserves. The National Nature Reserves ("NNRs") have stricter rules for establishment; their designation and subsequent construction projects must be permitted by the State Council of China (Guo and Cui 2015). They have historically received greater levels of funding (Ren et al. 2015) and been able to sustain more active management. In a survey of 535 Nature Reserves, Quan et al. (2011) found that NNRs had much higher management scores on average than provincial and municipal reserves.[2] Generally, Nature Reserves establish rules restricting use and prohibiting practices that could cause ecological damage, in keeping with national or provincial regulations. Most reserves include separate management zones with varying degrees of strictness of protection (Xu and Melick 2007). Some zones are very strictly protected while others allow for limited use, extraction of resources, or tourism development. There has been substantial heterogeneity in the actual management practices of Nature Reserves across time and space (e.g. Xu and Melick 2007). As with other protected area systems globally, enforcement efforts and establishment of local benefit-sharing mechanisms has depended on multiple factors including funding levels, local government structures, and context-specific historical arrangements or individuals (e.g. Xu and Melick 2007, Jim and Xu 2004, Ma et al. 2020).

Nature Reserves are spatially unevenly distributed, following overall patterns of urban-rural distribution in the country (see Appendix Figure A1). China's West is relatively less developed and more impoverished; Nature Reserves cover a larger percentage of land there and tend to be larger in size. The eastern portions of China are more industrialized; reserves are smaller, more numerous, and more likely to be managed at provincial and municipal levels (Cao et al. 2015). In addition, protected areas overall have tended to be sited in regions with higher altitudes, lower temperatures, drier environments, and lower vegetation productivities (Guo and Cui 2015, Cao et al. 2015). This is consistent with global trends for siting protected areas in more remote locations which are also likely to overlap with high pre-existing poverty (e.g. Joppa and Pfaff 2009). The process of designation of Nature Reserves highlights the importance of an empirical strategy that can account for other factors that may be correlated with the siting of

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[2] However, some literature also indicates that national level-reserves are not necessarily better funded. Xingkai Lake NNR, although national-level, was reported to have unstable funding that mostly came from the local government, hindering more ambitious projects to boost tourism and conservation (Su et al. 2014).

protected areas and also are determinants of economic development or of threats to natural land cover (e.g. Deng et al. 2011). Our empirical strategy is explained in Section 4.

2.2 Potential mechanisms of protected area impacts

Existing literature on the socioeconomic impacts of land protection and on eco-tourism in China's Nature Reserves points to several specific mechanisms by which land protection may affect household development and employment outcomes. On the potentially negative side, Nature Reserves may directly displace people, or restrict income generation due to prohibitions on extractive activities, agricultural land use, or industrial development. Protection of wildlife may also result in human-nature conflicts, primarily through increased wildlife damage to economically valuable crops. On the positive side, Nature Reserves can result in improved ecosystem service benefits, such as improved water resources or availability of timber and non-timber forest products, assistance from the state in excluding illicit resource extraction by others, direct employment opportunities as park guards or managers, and the potential for ecotourism-related economic opportunities. Ecotourism opportunities that boost household income may then lead to higher levels of education or health, either because individual households can afford those investments, or because the local revenue is used to improve school quality or healthcare facilities.

Prior studies from the Chinese context, using both qualitative and quantitative methods to examine cases of Nature Reserve impacts, indicate evidence for several of these specific channels. They also illustrate mixed overall results of protected areas on local livelihoods. Considering potential negative impacts, Ma et al. (2019a) found that the establishment of Qinling Nature Reserve had decreased crop income for residents, with the largest driver of this being the increased wildlife accidents. Wang et al. (2018) found that villagers' livelihoods were reduced after environmental protection regulations prohibited hunting, grazing, and logging, based on interviews with households in Shennongjia and Jiuzhaigou Nature Reserves. Shen et al. (2021) compared multidimensional measures of well-being for households inside and outside of 14 Giant Panda Reserves in Shaanxi and Sichuan provinces. They found perceptions of greater security for those inside the reserves but better material well-being and freedom of choice outside.

On the positive side, several studies indicate that parks in China have had success in bringing their villagers out of poverty through participating in ecotourism. Ecotourism may contribute to the sustainability of Nature Reserves through providing employment and attracting revenue, particularly in regions with fewer economic alternatives (Su et al. 2014). Ecotourism's rapid growth has been bolstered by economic development that has created a middle class in

China with disposable income and demand for outdoor recreation (Wang et al. 2012).[3] Indeed, between 1994 and 2009, the total number of domestic visitors within China increased fourfold: from 524 million to 1.9 billion in 2009 (Wang et al. 2012). A study of a thousand protected areas found that over 25% received over 500,000 visitors annually, and over 44% received over 100,000 people (Zhong et al. 2015). Many of China's Nature Reserves relied heavily on eco-tourism for much of their operating budgets during our period of study (Wang et al. 2012).

Considering patterns in the literature, the documented cases of improvements in economic well-being tend to be from parks that have strong visitation patterns and also have direct mechanisms for revenue sharing with local residents. For example, an in-person survey found that households near Jiuzhaigou National Nature Reserve increased their annual incomes after park establishment (Wang et al. 2018). In this case, village committees were official park stakeholders and helped to direct hospitality opportunities to locals. The income generated allowed people to buy houses in cities and send their children to better schools (Wang et al. 2018). Su and Wall (2012) similarly documented that Mutianyu villagers benefitted because they had the exclusive right to do business at the Great Wall in their area. They were also given income tax releases and easy access to apply for business licenses. In Shangxikeng Village in Sanqingshan, each family was allocated an employment position in the reserve's management agency, which itself funds construction of local businesses such as family hotels (Su et al. 2014). In Wolong Biosphere Reserve, although Fu et al. (2004) found an initial lack of employment opportunities, Liu et al. (2016) found that per capita income had increased due to infrastructure construction and commercial jobs in the reserve after ecotourism was developed. Zhang et al. (2021) found that households within the Wuyi Mountain Reserve in Fujian province had higher income than households outside, and that membership in a large family as well as technical assistance led to higher incomes. These instances of success highlight the importance of institutions that facilitate local employment in ecotourism to generate local economic gains, as well as the importance of proximity to sources of tourists.

At the same time, there are also situations in which ecotourism was not found to benefit local communities, or the benefits were not distributed equally. Ma et al. (2019a) found that Nature Reserves in Qinling reduced poverty overall for households within their borders, but also increased inequality between households. According to Quan (2011), only 6% of surveyed parks reported having communities participating in decision-making. Without any community involvement, the economic benefits of tourism may be directed to outside investors, sometimes including state-owned enterprises (Xu et al. 2009, Zhong et al. 2008, Zinda 2012). Inequality in

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[3] In addition, changes in employment structures have created more time for travel. In 1995, the five-day work week was introduced and in 1999, the government created the "Golden Week" holiday system, which consolidated certain holidays into three week-long vacations per year. During these times every year, millions of Chinese travel within the country, spurring increases in visits to Nature Reserves (Wang et al. 2012).

benefits may also be compounded if villagers do not have the necessary vocational skills for eco-tourism related jobs (Zinda 2012, Fu et al. 2004, Yuan et al. 2008). Consistent with this, Ma et al. (2019a) found that heads of households with higher education levels benefitted more from Nature Reserves. Revenue from parks may therefore create either positive or negative feedbacks. If income increases are sufficient, households may invest more in education and gain these skills, or shift to other more profitable types of jobs; if they are not, households may remain in lower income strata.

For these reasons, Nature Reserves may impact education outcomes, as well as employment trends more broadly. For example, Wang et al. (2018) found that local schools in Jiuzhaigou Nature Reserve historically offered education only up to middle school. However, when tourism increased local incomes, more people were able to pay for dormitories and entrance fees for schools in the nearby city of Chengdu. Liu et al. (2016) found evidence for employment shifts due to Wolong Nature Reserve. Household incomes increased through alternate sources of employment: households tended to shift from subsistence agriculture to cash crops, to gain temporary labor jobs on infrastructure construction, and to gain incomes through commercial jobs in tourism.

In general, we would expect that Nature Reserves could cause a shift away from primary and secondary industries and towards service-sector jobs which do not rely on extraction and are more compatible with ecological protection of resource areas. Both development outcomes and employment shares may also be impacted if internal migration is affected by protected areas. Prior case literature does not describe protected areas as a major push factor for internal migration, although there is some evidence that it can matter. Wang et al. (2018) found that villagers made rich by ecotourism near Jiuzhaigou NNR tended to move away to cities (often for better educational opportunities). In contrast, villagers in Shennongjia NNR, who were not made better off by the reserves, had fewer means to leave and were less likely to migrate.

We may also expect either positive or negative impacts on land-cover outcomes, depending on underlying pressures for land-cover change as well as management, enforcement, and support for alternate livelihoods (Hockings et al. 2000). The ecological success of Nature Reserves can depend on funding levels, which have been mixed (Ren et al. 2015, Su et al. 2014). Quan (2011) found that only 9.7% of surveyed parks stated that they had the resources to meet the requirements of protection. The complexity of agency jurisdictions, different legal arrangements among parks, and land tenure rights, as well as tensions among stakeholders, has also provided conflicting incentives and hindered enforcement efforts (Su et al. 2014, Cao et al. 2015). For example, challenges to reducing resource use have been documented in Wolong Biosphere Reserve (Fu et al. 2004, Song et al. 2021) and Pudacuo National Park (Zinda 2012). Zhong (2015)'s survey of protected areas found tree cutting in 7% of parks, wildlife poaching in

5%, collection of herbs in 11%, grazing in 12%, and damage to native trees in 15% (although some of these activities may be sustainable and beneficial local use in the long run). In Wolong Biosphere Reserve, officials chose not to continue enforcing restrictions when conflicts with local communities were high (Fu et al. 2004). Ecological conservation goals can also be compromised by the additional human activity brought by tourism (Liu et al. 2016).

At the same time, several prior studies have found examples of successful ecological protection in Nature Reserves. Ren et al. (2015) found that two thirds of National Nature Reserves have seen reduced rates of deforestation between 2000 and 2010 using a matching-based approach. In Wolong Biosphere Reserve, tourism infrastructure was found to have minimal local impact on vegetation, with trees being cut only to widen roads and new construction using only imported timber (Liu et al. 2016, Viña et al. 2007). Protected areas may also catalyze the use of environmentally-friendly technologies: for example, in Shennongjia National Nature Reserve, local firewood collection was reduced through energy-saving heating systems (Chen et al. 2005).

Our study draws upon this prior literature in seeking to test protected area impacts on dimensions of human development including material assets, education, and health, on employment impacts, including employment across sectors, and on land-cover change. Our next section details the data compiled to assess protected area impacts.

3. Study data

To analyze Nature Reserve impacts, we located and compiled census, protected area, elevation, eco-region, land use, river location, and major cities location data. Descriptions of these datasets and their sources can be found in Table 1. Our primary unit of analysis for socioeconomic impacts is a county, but we also analyze protected area units for the land-cover change outcomes. Socioeconomic outcome variables are from the published county-level aggregates of the Chinese census data (Table 1).

Some Nature Reserves are fully inside county boundaries, while others cross several county boundaries. To account for this, we use counties as our main unit of observation and construct the share of each county protected as the primary explanatory variable. There are 2,380 counties in 1982 and 2,873 in 2010; we account for these mergers and splits by using a system of aggregation to the smallest encompassing county unit.[4] This results in an initial dataset of 2,257 county units. The main policy variable of interest is the share (or percentage) of each county in a

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[4] To do so, we manually created "county units" or "supercounties" which are the smallest unit that still encompasses all the changes in other years. For example, if a county splits into two, we use the original boundary that includes both new counties. If several counties merge, we use the new boundary. We then aggregate the attributes of the smaller units appropriately: e.g. we add population tallies, and calculate population-weighted averages of percentages such as infant mortality. Geographic attributes are calculated for the county units.

Nature Reserve or other listed protected area[5] by the start of each time period. The Nature Reserves data used to construct this variable, which are polygons and establishment years, come from the 2013 version of the World Database on Protected Areas (WDPA), which was downloaded in that year. Details regarding the cleaning of this dataset to avoid duplicated areas, find missing establishment dates, and merge with the Chinese government's dataset on Nature Reserves can be found in Appendix A.

To assess impacts on household well-being, we used the census data to create a household development index (HDI) containing health, education, and household asset variables, similar to approaches used in the Global Multidimensional Poverty Index (Alkire et al. 2014) and other indices constructed to evaluate household well-being (e.g. Filmer and Scott 2008, Chakraborty et al. 2016).[6] Tables 2A-2D show summary statistics for all counties as well as those with more than 10% of land in protection by each time period. The variables used in each year for the HDI are also shown in this table. The HDI index is composed of health (infant mortality, healthy senior), education (middle school education or average years of education, literacy rate), and dwelling characteristics (has kitchen, has potable water, has bath facilities, has toilet, has hot water, has pipes in house). All of these are standard development indicators which may potentially be positively impacted by gains in household income, or by improvements to local infrastructure or ecosystem services accompanying protected area establishment.

To measure total employment, we use the data on the total percent of the population that is employed as reported in the census data for each period. This corresponds to formal employment reported to the government and includes agricultural occupations[7] (but may undercount informal employment). In addition, we use measures of primary ("first"), secondary ("second"), and tertiary ("third") industry employment for all years to measure shifts in types of employment. In the Chinese system, primary industry is identified as farming, fishing, logging, animal husbandry, and mining. Secondary industry is identified as construction, industry, and transportation. Tertiary industry is identified as services. Finally, we create a variable measuring those who are out of the labor force for reasons of education, working inside the home, or retiring.[8] According to our summary statistics, the percent of the population employed overall in

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[5] The large majority of protected areas (>2,000) were listed as Nature Reserves. Additional protected areas (about 50) include scenic areas, World Heritage sites, Biosphere reserves, and Ramsar sites. See Appendix A for further details on processing of protected area polygons.

[6] To create this index, we first transformed each variable using inverse hyperbolic sine in order to reduce the influence of outliers. We then standardized each variable to have a mean of zero and variance of one, summed them, and divided by the total number of variables. Variables with negative interpretations (infant mortality, illiteracy), were multiplied by negative one when used in the index.

[7] Employment includes government agencies and party organizations, professional or technical workers, people employed in commerce and service trades, production and transportation, and farming, forestry, livestock husbandry, fishing, and water conservation.

[8] If not employed, the categories in the census encompassing the non-working population are: Students in school, students not working because waiting for admission (only in 1990), household affairs, retired, disabled, don't have a

China increased between 1982 and 2000, changing from 50.7% to 76.2%, then slightly decreased between 2000 and 2010 (to 71.2%) (Table 2). The employment composition has also shifted over time: from 78.1% of employment in primary industry in 1982 to 59.6% in 2010.

The reliability of the accuracy of the census data may be questioned. The crucial assumption that we rely on is that any potential error in the reporting of socioeconomic data is unlikely to be systematically related to changes in the share of protected areas. Additionally, several studies have established reasonable reliability of the census data. China's 1982 census has been praised for its quality (Cai 2013) due to a relatively immobile society because of internal migration limits (*hukou* system); surveys conducted in parallel have also confirmed its reliability in terms of fertility, mortality, and marriage (Coale 1984). Banister and Hill (2004) concluded that the census over time is "generally good" and of "reasonable quality," improving coverage from each year to the next. Both Cai (2013) and Banister and Hill (2004) do raise concerns about the potential under-reporting of children because of the One-Child Policy, which could affect our total population variables. However, since our employment data is out of the population over 18 years old, these are unlikely to be affected. Finally, we note that several other published papers use the same decennial census data to construct similar types of data sets over similar periods of time (e.g. Wang and Chen 2016, Shen et al. 2017).

We used county boundaries and protected areas polygons to calculate a set of geographic covariates that may be related to the siting of Nature Reserves and to the development or land cover outcomes. These include elevation, ecoregion, distance to major rivers, and the distance to the closest of 26 major cities, using sources as described in Table 1. (Distances were calculated using centroid points for each county unit or protected area unit.) Summary statistics for these covariates are shown in Tables 2a-2d for county-level units.

To assess land-cover change impacts, as a measure of environmental protection, we calculate land cover for two types of units: the county units and for protected area polygons as units. We use 1980, 1990, 2000, and 2010 Landsat-based remote sensing raster data at a 1km scale from China's Land Use Status Remote Sensing Monitoring Database (Table 1). The data is classified into categories including settlement, forest, grassland, agricultural, and wetland area.

Finally, in order to investigate the role of protected area administration on socioeconomic and conservation outcomes, we combined government administrative data published on the website of the Ministry of Ecology and the Environment (MEE) with the Nature Reserve boundaries data from WDPA. We were able to match 1,554 out of the 1,955 Nature Reserves in our cleaned dataset with the government administrative data (see Appendix A). Summary statistics of the full sample and matched sample are displayed in Table 6. The

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job and looking for a job, and lost job and looking for a job. We sum the first three categories to create the "not in labor force" variable. This variable is available for 1990, 2000 and 2010.

normalized differences are small, indicating that the matched sub-sample with administrative data is likely to be representative of the entire sample.

4. Empirical strategy

4.1 Quasi-experimental approach: pre-matching plus generalized differences in differences

In a perfect experiment, parcels of land in China would be randomly assigned "protected" status. In such a case, any difference in socio-economic outcomes between the two groups would be plausibly attributed to the land being protected rather than to potential baseline differences between treatment and control groups. In reality, China's Nature Reserves are not randomly placed, and tend to cover more areas with high altitude, lower temperatures, drier environments and lower vegetation productivities (Cao et al. 2015). As described in Section 2, a crucial goal of protected areas in China has been to conserve biodiversity, and globally, the overlap between biodiversity and underlying poverty is large (Fisher and Christopher 2007). In addition, given that many Nature Reserves were established at the provincial or municipal level in China, areas with more wealth or administrative capacity may have expended more effort on establishing Nature Reserves. Clearly, endogeneity bias could arise in naïve inside-outside comparisons, with the underlying relationship between biodiversity and poverty likely to be misattributed to protected areas.

Absent a true experimental framework, our estimates rely on a combination of pre-matching to ensure similar treated and comparison groups at baseline plus panel regression with county and time-period fixed effects, controls for baseline covariates interacted with time trends, and controls for province time trends. This generalized differences in differences strategy exploits changes over time in the share of each county protected, with the identifying assumption of randomness in the timing of new protection, conditional on the included controls.

Prior to the panel regressions, we pre-process the data using Mahalanobis matching with calipers in order to match counties with a higher share of land in Nature Reserves to those that had a lower share but similar characteristics at baseline. Designs that combine panel regression with pre-processing matching techniques have been found to be more effective in terms of approximating a randomized control trial (Ho et al. 2007, Ferraro and Miranda 2017) and have been used in several prior studies of conservation policies (e.g. Alix-Garcia et al. 2015, Jones and Lewis 2015). For the purposes of this matching, we designate "treated" counties as those that received greater than the median share of protected land by 2010, and "untreated" as those that received less than the median share. The covariates used in matching are time-invariant geographic variables and socioeconomic characteristics from the baseline year (1982).

Specifically, we match on the following geographic characteristics: distance to nearest river, range of elevation, mean elevation, and percent of area in each ecoregion (Table A2), and on the following baseline socioeconomic characteristics from 1982: per-capita GDP, the share of the population with middle school education, illiteracy share, and total population. Calipers define a tolerance level for judging the quality of the matches; we use a caliper level of three standard deviations for the Mahalanobis metric. (This level is comparable to other studies in the literature such as Alix-Garcia et al. 2015, Ferraro and Miranda 2017, and Andam et al. 2010; we also check robustness to using other caliper levels in Section 5.)

According to these criteria, we use 1,360 counties out of the initial 2,257 for the regression analysis. Table 3 compares the baseline covariates for the matched and unmatched sets of counties. Without matching, we find that treated counties have less formal employment, less population, and are at higher elevation. Matching substantially improves the baseline balance of covariates across groups, with no variables having a normalized difference greater than 0.25 standard deviations, a recommended threshold for substantial difference (Imbens and Wooldridge 2009). The main cost of pre-matching in this context is that we lose a substantial portion of Western China (see Figure 2) because of a lack of good counterfactual counties that were similar at baseline but did not receive Nature Reserves. This is a limitation of the analysis, particularly due to the size of the land area and important regional distinctions. However, due to the distribution of population in China, which is more concentrated in the Central and Eastern regions (Figure A1), we still include 60% of the counties and 74% of the population that had at least 1% protected by 2010 in our assessment.

4.2 Household development and employment

The main estimation specification is a panel regression at the county level:

$$y_{ipt} = \beta_1 PctPA_{ipt} + \gamma_i + \delta_t + \Omega'(t * \lambda_p) + \Gamma'(t * X_i) + u_{ipt} \tag{1}$$

where *i* denotes county unit, *t* denotes year (1982, 1990, 2000, 2010), and *p* denotes province. y_{ipt} is the county-level economic outcome in each time period. These outcomes include the household development index, total employment, and employment by industry.

$PctPA_{ipt}$ is the policy variable of interest: the percentage of county *i* (measured as a decimal from 0 to 1) in province *p* that is protected by time *t*. γ_i are the county fixed effects, δ_t denotes the time fixed effects and $t * \lambda_p$ are a series of provincial linear time trends. Because provinces have developed at different rates (e.g., provinces in the east have developed most rapidly on average); this control allows for these different growth trends over time. In addition, the final term specifies the inclusion of interactions between the baseline geographic and socioeconomic covariates used in matching and time $(t * X_i)$. We estimate all models using heteroscedasticity-robust standard errors, clustered by county unit.

Because our data includes repeated observations of the same counties, we identify impacts from variation over time in the establishment of new protected areas, conditional on the included controls. County fixed effects absorb unobserved, unchanging factors in each county that may influence both socioeconomic outcomes and protected area variables, such as soil fertility, efficiency of local government, and proportion of minority population in the county. Time fixed effects absorb socioeconomic shocks over time that are common to all counties, such as the implementation of new national economic policies, and province time trends capture differential growth across regions. The interactions between baseline covariates and time allow for differential trends across counties that may be driven by geographic or historical county-specific characteristics. Therefore, the key identifying assumption in this panel regression is that the remaining variation in protected area share—conditional on this full set of included controls—is unrelated to potential economic outcomes. Our results may be interpreted as causal impacts to the extent that this assumption is fulfilled.

Figures 1 and 2 offer support for this assumption. Figure 1 illustrates that protected areas were established over time throughout the country with substantial regional variation. Figure 2 maps the residuals for the 2010 period from a specification where the share of each county protected is regressed on the county and time fixed effects as well as regional growth trends and baseline covariates interacted with time. The figure indicates that there is remaining variation in the share protected—after controlling for growth trends and fixed characteristics—that is plausibly random across space. In addition, as a check on potential differences among those counties that would have a higher share protected in later periods, we test whether the percent of county area protected in the latest two periods is significantly related to prior period characteristics (Table A1). We find that the lagged HDI, population density, percent in primary industry, and percent employed do not together significantly predict subsequent changes in the percent protected.

The establishment of Nature Reserves occurred in parallel with other forest reforms and government programs designed to support ecosystem services, including a large-scale logging ban, subsidies for restoration, and forest tenure reform.[9] Although officially operating separately

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[9] Nature reserves are part of a multi-pronged forest protection strategy in the country. Forest protection started in the late 1970s, with programs such as the Three-North Shelter Forest Program that targeted forest restoration to prevent desertification. This program covered 13 provinces including autonomous regions in Northern China. A series of large-scale forest protection programs were initiated in the 1990's, including the Natural Forest Protection Program in 1998 and the Sloping Land Conversion Program (SLCP) in 1999, in response to a number of natural disasters in the Yellow and Yangtze River Basins (State Forestry Administration 2003, Xu et al. 2006b, Uchida et al. 2009, Fu et al. 2019). The NFPP included a logging ban in natural forests upstream of the Yangtze River and the Yellow River as well as the midstream of the latter, and reduction of logging in key state-owned natural forests –

from Nature Reserves and often targeting different types of land, these programs also tend to be targeted to areas with substantial forests, wetlands and other conservation-worthy natural assets. Our specifications include county-level fixed effects to account for underlying differences in the share of land in natural areas as well as province time-trends that may allow for differential growth in economic activity within provinces particularly affected by these other programs. Time-period fixed effects also absorb the broad roll-out of these programs, but they may pose a limitation as a confounding factor in some cases.[10]

It is additionally important to note that during our period of study, the Chinese economy experienced major structural shifts. These included large transitions away from jobs in state-owned enterprises (particularly between 1995 and 2002), dramatic increases in rural-urban migration in the 1990's and 2000's, and a strong increase in college enrollment, particularly in the 2000's (Feng et al. 2017, Meng 2012). Our use of time and county fixed effects as well as province time-trends and interactions between baseline covariates and time are crucial for controlling for these overall labor market changes in evaluating the impacts of protected areas. As a further check on the possibility that regions may have experienced particularly important differences in each time period, we include a robustness test with additional region-by-year fixed effects for the Eastern, Central, and Western regions (Table A3).

4.3 Land cover change

To evaluate the conservation impacts of Nature Reserves, we estimate impacts on land cover outcomes within the protected areas themselves. For these specifications, the unit of analysis is a polygon, with the set of polygons being those areas that are or will be protected between 1982 and 2010. We estimate a similar model:

$$IHS(y_{rpt}) = \beta_1(isPA_{rpt}) + \gamma_r + \delta_t + \Omega'(t * \lambda_p) + \Gamma'(t * X_r) + u_{rpt} \qquad (2)$$

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mostly located in the three northeastern provinces of Heilongjiang, Jilin and Inner Mongolia. The SLCP, also known as Grain for Green, was a large-scale program across 25 provinces that provided public payments to compensate rural households to convert cropland to forests (Bennett 2008). In addition, China's forest tenure reform decentralized the majority of its forestlands (58%) that were legally owned by village collectives and gave management rights to private households (Xu et al. 2010, State Forestry Administration 2011). These initiatives occurred mainly between 2003 and 2010 and were found to encourage rural households' investment in forest and improve the efficient use of forestland (Yi et al. 2014, Yi et al. 2023). Liu et al. 2010, 2014 and Mullan et al. 2009 investigate the impacts of these priority forestry programs on household incomes.

[10] As Zuo (2001) described for SLCP, these types of policy implementations follow a top-down approach in China, starting with determining the distribution of quotas or targets from the central government to the provinces, and then the provincial government assigning subsequent distributions down to counties, who then further mediate between provincial governments and villages/households together with township governments. If these other programs were changing at the same time and in the same counties along with Nature Reserve designations, that could potentially bias our results, with the other programs accounting for part of the results attributed to Nature Reserves. Unfortunately, comprehensive spatial data over time at the province level on these other programs is not available.

Where r denotes Nature Reserve. $IHS(y_{rpt})$ is the outcome variable, specifically the Inverse Hyperbolic Sine transformed percentage of each land cover class (forest, human settlement, agriculture, grassland, or wetland). Protected area status is measured in this case by an indicator variable ($isPA_{rpt}$) that is equal to one if the Nature Reserve is established prior to that date. The specification includes protected area and time fixed effects and the same province trend controls and interactions of time by baseline covariate trends as above (per-capita GDP, middle school education, literacy, population, distance to river, range of elevation, mean elevation, and share of each ecoregion). These socioeconomic covariates are taken from the county that the Nature Reserve falls within. If it falls within multiple counties, covariates are a weighted average based on the population of each county and the percent of the Nature Reserve area in each county. In order to compare results for land cover to socioeconomic results that use county-level units, we also estimate a specification with land cover change measured at the county-level using a model similar to Equation 1.

4.4 Heterogeneous impacts

In addition to estimating average effects, we seek to understand heterogeneity across potential mediating factors. We estimate specifications following those described above, including interaction terms to allow county-level or protected area impacts to vary by other characteristics. We calculate differential impacts based on geographic location: distance to nearest river, mean elevation, and distance to cities, and human characteristics: population density, baseline assets, and time periods. These human factors are policy-relevant because, for example, concern exists that the development of eco-tourism in protected areas may cause inequality to increase, with areas that were least developed at baseline tending to be left behind (e.g. Barrett et al. 2011, Yang et al. 2019). Thus, analyzing development and employment trends at different levels of baseline assets can shed light on this concern. Finally, as studies based on surveys of park managers have documented potential differences depending on the level of government managing the reserve (Yang et al. 2019, Quan et al. 2011), we also estimate heterogeneous impacts for different Nature Reserve administrative levels.

5. Results

5.1 Household development index, employment

Our primary research question is how Nature Reserves affected overall socioeconomic well-being of households, as measured through the household development index (HDI). We find that Nature Reserves, on average, increased household well-being (Table 4, Column 1), with an estimated coefficient of 0.152 standard deviations. For the average share protected among counties with some protection (6.9%), this corresponds to an estimated increase of 0.0105 standard deviations in the HDI (going from 0 to 0.069 in the share protected). Considering separately the education and health components of the household development index, we find estimated positive gains in both components, with a statistically significant estimated gain in the education component specifically (Table 4, Columns 2 and 3).[11]

These results are generally robust to variations in the pre-matching design and the weighting of the HDI variables. In Table 5, part A, we check the robustness of the positive HDI results to alternate choices of the cutoff used to determine treatment in the pre-matching step. In Table 5, part B, we vary the weighting of the index components and the size of the calipers used to determine matches. We find that the results are fully robust in sign to these choices and are robust in significance to a lower threshold used to determine treatment, stricter calipers, and omitting the dwelling characteristics from the HDI.[12] Additionally, the results are robust to including region by year fixed effects for the Eastern, Central and Western regions of China (Appendix Table A3).

Although positive and statistically significant, the estimated magnitude of the impact on HDI is small compared to findings from some other countries,[13] but is also consistent with the generally small socioeconomic impacts of protected areas summarized by recent meta-analyses (e.g. Oldekop et al. 2016, Ma et al. 2020, Kandel et al. 2022). We may also characterize the results as relatively small in magnitude compared to other possible environmental policies that have been shown to improve human well-being in China. For example, a growing literature has demonstrated that reducing air pollution can substantially improve life expectancy and health outcomes (e.g., Ebenstein et al. 2017; Zhou et al. 2015; Fan et al. 2020; He et al. 2020).[14] At the same time, our results establishing that the average impact of Nature Reserves on human development indicators was positive is important given the lack of previous analysis on this question.

While the HDI impacts are positive, we find negative estimated impacts on reported employment (Table 4, Column 4) and shifts in the composition of employment (Table 4, Columns 5 and 6). We measure composition in terms of shifts from more resource-intensive primary and secondary industries to service-based tertiary industries. Here we find a statistically significant decrease in the percentage of formal reported employment associated with a greater

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[11] Dwelling data were only collected for 2000 and 2010 (Tables 2A-D indicate the variables used in the HDI each year.)

[12] We also used analysis of the residuals and an alternate quadratic specification to explore possible non-linearity in the relationship between share protected and our outcomes. This supports the choice of a linear specification for the percent protected.

[13] E.g. Naidoo et al. (2019) evaluated the impact of protected areas on human well-being using a global-scale sample of 34 developing countries and found that households with proximity to protected areas had higher wealth levels (by 17%), lower likelihood of poverty (by 16%), and higher score of height-for-age for children under 5 years old (by 10%); Andam et al. 2010 reports poverty reduction due to protected areas with effect sizes of 0.22 to 0.30.

[14] E.g. He et al. (2020) also found that a policy that aims to reduce air pollution—i.e., a 4.33 $\mu g/m^3$ decrease in mean $PM_{2.5}$ concentrations would reduce mortality rate by 1.41%, and this may avert 18,900 premature deaths annually.

share in Nature Reserves. Again, these magnitudes are relatively small. We find an estimated coefficient of -2.6 percentage points (ppt) lower employment for a change from 0 to 1 in the share protected variable. A change from zero to the average share protected of 6.9% thus corresponds to a 0.18 ppt estimated decrease in employment. In addition, we find that Nature Reserves led to a statistically significant decrease in the share of employment in primary industries (-0.015 coefficient, or 0.104 ppt decrease going from zero to the average share) and a negative but not statistically significant decrease in secondary industry (-0.011 coefficient). These findings are consistent with reductions in extractive activities and possible constraints on industrial activities associated with Nature Reserves. The estimated coefficient for the share of employment in tertiary industry, however, indicates a gain in tertiary industries that is marginally statistically significant ($p < 0.10$) and a coefficient of 0.026 or a 0.18 ppt estimated increase in the share of employment going from zero to the average share protected. Growth in tertiary industries is consistent with additional service-based employment opportunities related to tourism. Indeed, employment is a link between conservation and development; a success in shifting employment towards services is likely to be a key to long-term conservation success. Our results are consistent with evidence that this shift took place, but the overall total employment loss indicates that gains—at least in reported employment—have not been large enough to fully cover the losses. We further explore the heterogeneity in these overall results and possible explanations in section 5.3.

5.2 Land cover change

We investigate changes in forest, agriculture, grassland, settlement, and wetland land cover both within the boundaries of protected areas and within county-level units. Summary statistics for the Nature Reserve polygons show that total forest cover has changed very little inside of the boundaries of areas that were or would become protected throughout this period (Table 6). Forest cover has consistently remained close to 47% on average from 1980 to 2010, declining by just 0.2 ppt between 1980 and 2010. Grassland and agricultural land have similarly changed very little, decreasing by 1 ppt in total and remaining close to 16% and 25% respectively. Wetland cover has also seen a small decrease of 0.2 ppt. We find larger but still relatively small amounts of conversion to human settlements within Nature Reserves, with the share of land area in settlement increasing from 2.1% to 3.4% on average across these decades.

Within county units (Table 2), we find similar trends for all counties across the country. Forest cover has remained quite stable on average, albeit with a lower average level of approximately 31% across county units as a whole. The average share of land in agriculture and grasslands has decreased a small amount at the county level from 1980 to 2010 (39.5% to 38.5%; 17.8% to 17.3% respectively), while the share of land in settlements has increased (4.3% to

5.9%). Some areas did see substantive change: 155 county-time period observations indicate a loss of more than 1 ppt of forest cover and 11 lost more than 5 ppt. However, compared to global trends of forest loss and land cover change (e.g. FAO/UNEP 2020), these trends indicate quite stable overall land cover within China across these decades.

Table 7 shows results for regressions of land cover outcomes with the Nature Reserve polygons (Columns 1 to 5) and counties (Columns 6 to 10) as the units of observation, respectively. Using changes over time in protected status within the areas that would become Nature Reserves (Equation 2, Columns 1 to 5) gives our best estimate of the possible causal impacts of protection for those areas actually preserved. Using changes over time for the counties as a whole (similar specification to Equation 1, Columns 6 to 10) incorporates potential leakage or slippage of land-cover changes outside of these areas but within the associated counties.

Within Nature Reserve polygons, we do not find statistically significant evidence that protected area designation impacted land cover change. However, the magnitude of these results indicates an approximate 17.0% increase in forest cover and a 10.7% decrease in settlement cover associated with full protection. At the mean value of forest cover inside parks (47%), this implies that protected areas may have increased forest cover by about 7.7 ppt compared to the counterfactual of no protection. At the mean value of settlement cover (3.0%), protected areas are estimated to reduce settlement cover within their boundaries by just 0.32 ppts. Similarly, the impact on grassland cover is approximately -3.5 ppts at the mean and the impact on wetlands is about -0.11 ppts. Together, these estimates indicate that the designation of protected areas likely maintained natural land cover within their boundaries but did not have a clearly statistically significant impact compared to the counterfactual. This inability to detect a statistically significant impact is likely because of the overall low changes in land cover as a whole throughout this period.

As noted above, we also assess changes in land cover within county units in order to match the unit of analysis of our socioeconomic outcomes (Table 7, Columns 6 to 10), keeping in mind that these estimates reflect land-cover changes in areas that are both protected and not protected within each county. At the county-level, we again do not find estimated impacts of a greater share protected on land cover changes that are large or statistically significantly different from zero at a 5% level. The coefficients do imply a marginally statistically significant ($p < 0.10$) overall increase in agricultural land use in counties with a high share protected. We also see point estimates indicating an increase in wetlands due to protected areas, a small reduction in overall forest cover, and a moderate reduction in grasslands and settled land. Although these results are not statistically significant, they do suggest potential spillover implications. They indicate that while Nature Reserves increased forest cover within their own boundaries, they did not lead to a net increase within counties, indicating possible displacement of deforestation to other locations within the same county. This is consistent with reports of deforestation happening in the perimeter outside reserve borders (Viña et al. 2007, Zhao et al. 2011). At the same time, these estimated changes are small in magnitude. For the average share protected (6.9%) and average county level forest cover (31%), protection is estimated to reduce county-level forest cover by just 0.11 ppt, to increase agricultural land by 1.25 ppt and to reduce grassland by 0.27 ppt. In addition, the coefficients imply a small decrease in overall land converted to settlements. Based on the average share protected and at the typical settlement percentage (5%), there was an approximately 0.09 ppt decrease in settled land cover at the county level. This suggests that on average, Nature Reserves did not substantially constrain county-level development of human settlements.

Taken together, these results indicate that Nature Reserves in China were largely effective in maintaining existing natural land cover types within their boundaries and did not have large estimated impacts on land cover on average at the county level—although these averages may mask important heterogeneity or tradeoffs across impacts, as explored further in the next section.

5.3 Heterogeneity in impacts

Conservation policies have previously been found to have substantially different impacts depending on management level, location and type (Sims 2010, Ferraro, et al. 2011, Pfaff and Robalino 2012, Ferraro et al. 2015, Oldekop et al. 2016, 2019). We analyze heterogeneity in impacts in order to better understand how protected areas have affected different subpopulations, in the Chinese context.

In Table 8, we consider heterogeneity across the full range of outcomes, for dimensions of access to markets, baseline poverty, and time. To do so, we estimate regressions with interaction terms between share protected and each of these covariates and then provide estimated impacts at the 25th, 50th, and 75th percentile values for each of the covariates based on the combined coefficients from those regressions. We consider the same set of counties and use the same additional controls as the main specifications (i.e. Equation 1 and Table 4).

We find greater positive impacts of protected areas on the household development index for counties that are closer to rivers, closer to cities, at lower elevation, at higher population density, and that have greater baseline assets (Table 8, Column 1). These measures include geographic factors which may be correlated with access to markets and tourists due to the historical role of rivers in trade and transportation. Greater baseline assets may also indicate higher levels of capital or skills that can be used in the ecotourism industry. These patterns are similar to those observed for the shift towards tertiary employment (Table 8, Column 5). We find that protected areas were associated with greater increases in service sector employment shares closer to cities, at lower elevation, at higher population density, and where households had greater baseline assets. This is consistent with increases in HDI being related to a shift towards tourism-based employment resulting from parks in places where there are more opportunities to attract tourists. In addition, we find that the increases in HDI associated with parks are greater over time, with the largest positive impacts driven by gains in the two most recent periods. This is also consistent with the increasing decentralization of park planning and the development of ecotourism to support parks as documented in Section 2. However, these trends potentially also indicate widening inequality, with more remote households continuing to be left behind.

We also find that the patterns of estimated positive impacts on the HDI and tertiary employment correspond to patterns of estimated negative impacts for the overall percentage of the population employed. Heterogeneity in the estimated reductions in employment associated with Nature Reserves (Table 8, Column 2) tends to also correspond to factors related to urbanicity: we find larger employment decreases in counties closer to cities, at lower elevation, higher population density, with higher baseline assets, and in more recent time periods. This presents a puzzle regarding how HDI and tertiary employment may increase while overall employment does not.

A first possible explanation is that while ecotourism may have boosted the share of people employed in the services sector, employment gains in this sector have not been enough to keep pace with strong employment growth in manufacturing and industrial sectors during this time. Counties that did not have any restrictions due to Nature Reserves may have been better able to take advantage of these overall employment opportunities driven by China's Economic Reform policies.

A second potential explanation is that the HDI increases due to protected areas are coming from informal employment such as selling goods or food to tourists or providing homestay lodging or private transportation, but not from permanent or official employment. In this case, living standards may increase while reported employment does not. Related to this possibility is the idea that with better living standards, more rural families can send children to advanced secondary school or college (supported by the positive estimate on the education component of the HDI), or more family members can work inside the home or officially retire. This explanation would also account for the reduction in the total percentage of people employed, but has a more positive social interpretation because human capital and choice have increased due to protected areas. To test this possibility, we analyze impacts on the percent of total population doing housework, in school, and retired ("not in the labor force"; Table 8, Column 3). While we do not find statistically significant impacts on being outside of the labor force, we do find positive point estimates. In addition, we find that the patterns of greater positive impacts on this variable did generally match the patterns of greater negative impacts on the percent of people employed. This suggests that shifts in labor force participation may explain part of the difference between HDI results and employment results.

Third, an additional explanation is that migration could play a role, with apparent gains in HDI driven by poorer households moving away from counties with a high share of Nature Reserves or richer households moving in. To explore this within our study scale, we use population density as an outcome variable and repeat the main specification to estimate the impact of protected areas on population density. We find a positive but not statistically significant coefficient, indicating that new land protection did not result in substantial net outmigration. If anything, it slightly attracted additional residents compared to similar areas, which could also partly explain the lower employment rates.

Finally, it may be the case that the improvements in household development associated with land protection are the result of direct infrastructure improvements from the government related to establishing Nature Reserves (e.g. investments in housing, water, or sanitation). This type of development could raise HDI without boosting employment. This hypothesis is difficult to assess further without full historical data on the locations of such government investments over time, but would be a crucial question for future research.

In addition to heterogeneity in socioeconomic impacts, we also consider additional heterogeneity in the land cover outcomes (Table 8, Table 9). In Table 9, we use the matched administrative data to test for evidence that the administrative level of control, the managing department, or the conservation objectives matter for estimated impacts on forest cover within reserves. We interact protected area status with whether the area is a national-level Nature Reserve, whether "forest" is listed as a conservation objective, whether the managing department is the Ministry of Forestry, and whether the type of reserve is a Forest Reserve. Prior literature suggests greater funding available for National Nature Reserves, which might suggest greater environmental effectiveness in the preservation of forest resources. Consistent with this, we find a positive interaction coefficient for National Nature Reserve status (Column 1), but it is small and not statistically significantly different from zero.

We also find that areas managed for reasons other than forest conservation and not by the Forestry Department saw a greater apparent positive impact on the average share of forest cover (Columns 2 to 4). This could be due to more of a focus on production forestry for the properties managed by the State Forestry Administration (which could then show as losses in some periods), whereas other properties may be managed more for wildlife habitat or non-timber forest products. Considering each level of management and each type of land cover separately (Appendix Table A4), we do not find statistically significant impacts. However, according to the point estimates, National Nature Reserves have the largest and positive coefficients with respect to forest cover and a decrease in settlement cover, while Provincial Nature Reserves have negative relationships with forest cover and increases in settlement cover, again consistent with possible differences in effectiveness. Given the changes in level of designation and control over time, these types of institutional heterogeneity also deserve additional future study.

Finally, Table 8 provides the estimates of heterogeneous impacts for each land cover type at the county level (Columns 6 to 10). The results for forest cover are not statistically significant but indicate possibly greater loss associated with Nature Reserves in more remote or poor areas and in the earlier time periods. To the extent that Nature Reserves reduced conversion to settlement cover, they had stronger effects closer to rivers and cities and at higher population densities. However, increases in agricultural cover associated with protection were also greater closer to rivers, cities, and at higher population densities, while grassland cover decreased by more in similar types of locations. Overall, the comparison of patterns of heterogeneity in the socioeconomic outcomes versus land cover outcomes shows differences across locations but does not point to a systematic set of conditions clearly predicting tradeoffs or win-win situations. This may indicate that specific local histories and institutions for direct local benefit sharing—as emphasized by the case study literature—play an important role in determining joint environment and development gains.

6. Conclusion

Scientists and global policymakers have called for the protection of at least thirty percent of terrestrial and marine areas by the year 2030 (Dinerstein et al. 2019). While clearly important for global biodiversity and climate stabilization, these goals potentially directly affect the livelihoods of half a billion people across the world (Schleicher et al. 2019), including many within China.

Our analysis of the impacts of Nature Reserves in China contributes to the necessary understanding of how land protection may affect people and local communities. This study offers the first national-level, quasi-experimental analysis of the impacts of China's Nature Reserves. We analyzed indicators of both conservation and development and how these outcomes differed across dimensions of access to markets, baseline poverty, time, and geographic characteristics.

Using panel data from 1980 to 2010 and plausibly exogenous variation in the timing of new land protection, we found positive average impacts of China's protected areas on household development, and a shift away from employment in the industrial and manufacturing sectors towards employment in services. We found that gains in household development due to protected areas were greatest in areas with high baseline assets and that likely had more access to tourists by being closer to settled areas. We found evidence based on remote-sensing data spanning the same decades that Nature Reserves maintained forest cover within their boundaries and did not pose substantial constraints to the growth of settlements. Together, these results indicate the strong potential for protected areas to be an important part of regional development strategies.

At the same time, we found that Nature Reserves appear to have led to a decrease in the reported share of the population employed. While this may indicate choices to work informally, to invest in additional education, or to retire, it may also reflect a lower availability of jobs for counties with substantial area protected, compared to those without. We also found that increases in service sector employment due to Nature Reserves were greatest in areas with the highest baseline assets, possibly suggesting inequality in the gains from tourism.

Additional work is needed to fully understand the specific mechanisms by which protected land areas are affecting local communities, and particularly how these impacts may have changed in the most recent decade of China's experience. Challenges in maintaining future land cover and biodiversity may be greater than in the past. Due to rising standards of living, China's urban land area is expected to increase by almost 400% between 2000 and 2030—the largest projected increase in the world (Güneralp and Seto 2013). Yang et al. (2019) projects that from 2000 to 2050, 5016 km^2 of Nature Reserves may be in potential tension with human settlement, while new fragmentation may be expected in 243 Nature Reserves and increased fragmentation in 109 Nature Reserves.

If tourism and sustainable resource use do not provide employment opportunities that can keep pace with growth in more urban areas, this highlights the importance of continued allocation of support to rural areas that are supporting conservation. This may be achieved through mechanisms such as direct investment from the central government, payments for ecosystem services for additional voluntary conservation (e.g. Lu and Yin 2020), or additional jobs that are tied to protected areas. Indeed, poverty alleviation has already been identified as a top concern for China's proposed new system of National Parks. In the pilot park Sanjiangyuan in Qinghai province, the "One Family, One Ranger" program seeks to hire one family member in each household for 1800 yuan ($255) per month to support park conservation through trash collection or monitoring illegal poaching (Larson and Wang 2019). Similar programs may be important to support other protected areas. As China continues to forge its path of evolving ecological civilization, policies that attempt to reconcile conservation with development, as well as detailed and up-to-date information on land protection, should continue to be a priority to ensure management that can balance both objectives.

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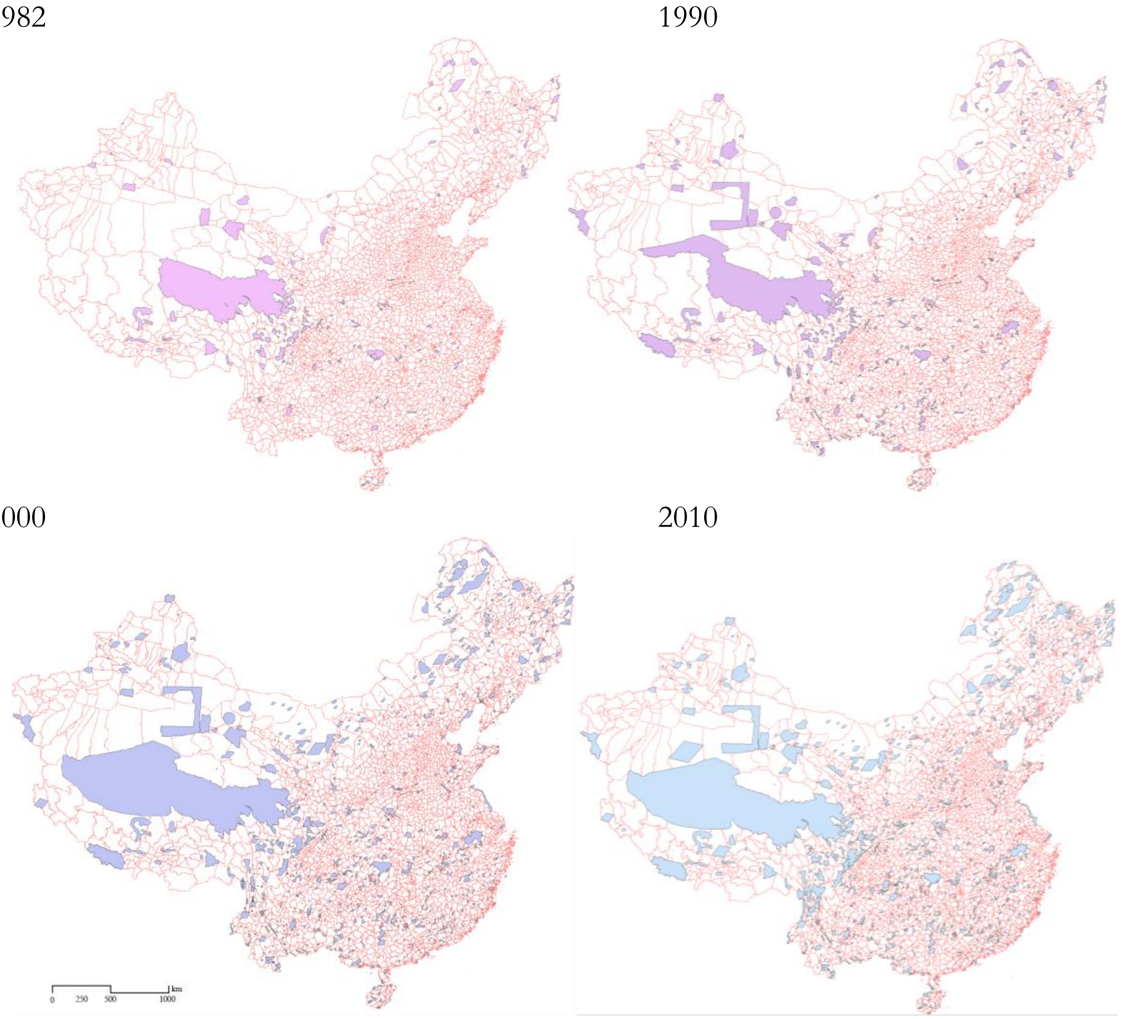
Figures and tables

FIGURE 1. PROTECTED AREAS: 1982, 1990, 2000, 2010



1982

1990

2000

2010

Figure shows growth over time in the boundaries of protected areas established by each date listed. Solid polygons are protected areas; open polygons are county units. Protected areas data is from the IUCN World Database of Protected Areas (accessed in 2013).

Figure 2: Residuals of Share Protected

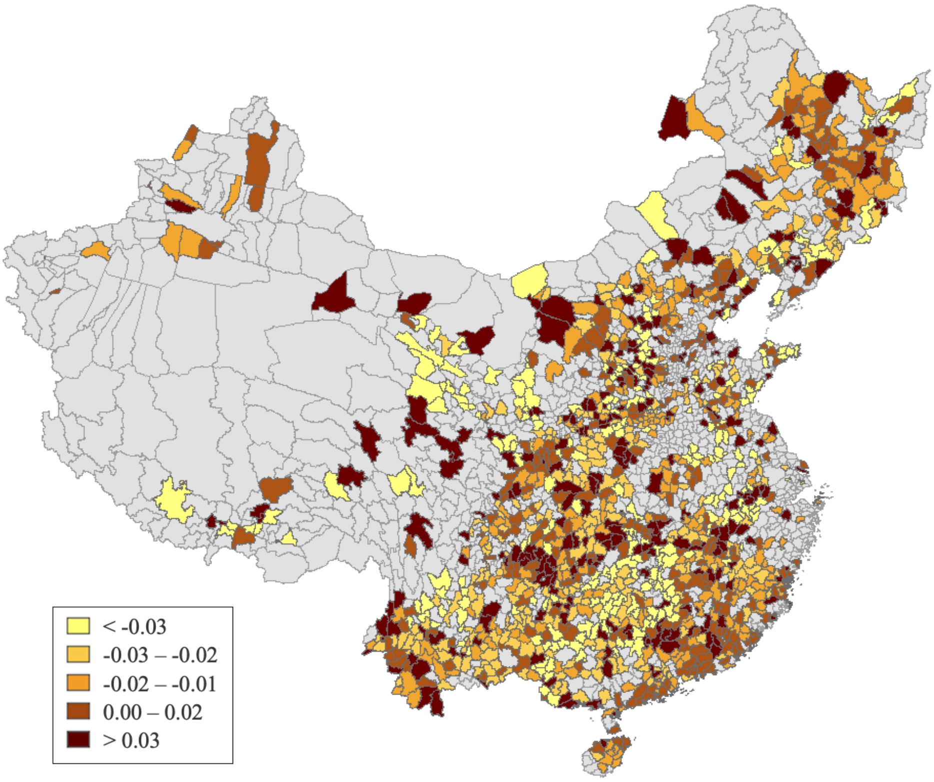


Figure shows the residual of the share of protected areas in 2010 not explained by county fixed effects, time fixed effects, province time trends and covariate*time trends for the matched set of counties.

TABLE 1: DATA AND SOURCES

Dataset	Description	Citation
China County Population Census with GIS Maps (2010)	The population census covered all persons who hold the nationality of, and have permanent residential place in the People's Republic of China. Shapefile and census data aggregated to county level.	China Data Center. 2014. "China 2010 County Population Census Data with GIS Maps. [Electronic Resource]." Version III. University of Michigan.
Historical China County Population Census Data (1953-2000)	The population census covered all persons who hold the nationality of, and have permanent residential place in the People's Republic of China. Shapefile and census data aggregated to county level.	China Data Center. 2005. "Historical county population census data with maps: 1953, 1964, 1982, 1990, 2000." All China Marketing Research Co. Ltd.
World Database on Protected Areas (2013)	2,166 protected areas including forest parks, wetlands, geoparks, etc.) in China. Data submitted by various government agencies and NGOs.	World Database of Protected Areas. 2013. "China." Protected Planet. Protectedplanet.net/country/CHN (last downloaded in 2013).
Protected Areas Administrative Data (2013)	A complete government-issued list of protected areas that contains the government level, type of area, establishment date, ministry in charge, and target protected species.	Ministry of Ecology and the Environment of the People's Republic of China. 2013. "2013 年全国自然保护区名录" ("List of Protected Areas in China in 2013"). www.mee.gov.cn/ywgz/zrstbh/zrbhdjg/201605/P020160526589088556998.pdf
Terrestrial Ecosystems of the World (Biomes)	Spatial data on ecoregions: distinct assemblages of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change.	Olson, D. M. et al, 2001. "Terrestrial Ecoregions of the World: A New Map of Life on Earth." *Bioscience 51*(11): 933-938.
ArcGIS Dynamic World Elevation Terrain	Numeric values representing ground surface heights, based on a digital terrain model (DTM). Heights are orthometric (sea level = 0). Esri subscription required.	Esri. 2020. "Terrain." Esri Living Atlas. https://elevation.arcgis.com/arcgis/rest/services/WorldElevation/Terrain/ImageServer.
26 Natural Cities of China (1992-2012)	Shapefiles of 26 major cities in each year: naturally or objectively defined human settlements based on a cutoff averaged from geographic information: points of interest, social media location data, and time series nighttime images.	Jiang B. 2015. "Head/Tail Breaks for Visualization of City Structure Dynamics." Cities 43: 69-77. https://doi.org/10.1016/j.cities.2014.11.013.

China Land Use Remote Sensing (1980, 1990, 2000, 2010)	1-km raster data. A multi-temporal land use status database covering the entire land area of the country. The data production is based on Landsat TM / ETM remote sensing images in each issue as the main data source and is generated by manual visual interpretation.	China Academy of Sciences. “1980 年代末期（1990 年）中国土地利用现状遥感监测数据” (“Land Use Remote Sensing Data”). Resource and Environment Data Center. http://www.resdc.cn/data.aspx?DATAID=95.
Major Rivers of China	China's first-level river spatial distribution data set is the first-class rivers such as the Yangtze River, Yellow River, and Heilongjiang, which are extracted from the 1: 1 million river data in China.	China Academy of Sciences. “中国一级河流空间分布数据集” (“China’s first-level river spatial distribution dataset”). Resource and Evironment Data Center. http://www.resdc.cn/data.aspx?DATAID=221.
Population Density in China, 2010	1-km raster. See linked data repository for original data source and description.	Wang, L., and Chen, L. (2016). Spatiotemporal Dataset on Chinese Population Distribution and its Driving Factors from 1949 to 2013. Nature Scientific Data 3:160047. Retrived from https://figshare.com/collections/Data_from_spatiotemporal_dataset_on_Chinese_population_distribution_and_its_driving_factors_from_1949_to_2013/3291368

TABLE 2A: 1980/1982 SUMMARY STATISTICS

	All counties (2,261)		>10% PA (37)	
	Mean	Standard Deviation	Mean	Standard Deviation
Basic Characteristics				
Total population	442,126	442,268	269,342	261,645
Elevation (km)	0.868	1.101	1.153	1.118
Distance to river (m)	562.025	593.917	652.646	652.343
Household Development Index Variables				
Overall index	0.000	0.72	-0.003	0.684
Middle school education (%)	0.160	0.062	0.165	0.055
Infant mortality	37.420	25.871	45.348	26.547
Illiteracy (%)	0.359	0.153	0.321	0.114
Employment Variables				
Employed (%)	0.507	0.058	0.483	0.066
1st industry (%)	0.780	0.183	0.705	0.217
2nd industry (%)	0.120	0.132	0.171	0.166
3rd industry (%)	0.100	0.065	0.124	0.060
Land Cover Variables				
Forest cover (%)	0.313	0.278	0.430	0.278
Settlement cover (%)	0.043	0.062	0.054	0.158
Agricultural cover (%)	0.395	0.270	0.237	0.201
Grassland cover (%)	0.178	0.209	0.175	0.184
Wetland cover (%)	0.009	0.032	0.003	0.006

County-level economic characteristics are from 1982 and land cover variables are from 1980. All variables marked "(%)" are from 0 to 1. Infant mortality is measured in number of babies who died within one year per thousand live births. Employment industry is measured as the percent employed in each industry out of total population employed. First industry is resource extraction (farming, fishing, mining, agriculture), second industry is construction and industry, third industry is services. Infant mortality and illiteracy are added into the household development index as their negative values.

TABLE 2B: 1990 SUMMARY STATISTICS

	All counties (2,261)		**>10% PA (178)**	
	Mean	Standard Deviation	Mean	Standard Deviation
Basic Characteristics				
Total population	499,994	512,649	336,865	326,562
Total households	122,470	139,175	81,197	85,346
Distance to nearest big city (m)	814.854	922.62	1058.823	1024.296
Elevation (km)	0.868	1.101	1.15	1.139
Distance to nearest river (m)	562.025	593.917	627.461	632.948
Household Development Index Variables				
Overall index	-0.000	0.869	-0.134	0.866
Infant mortality	80.118	54.216	97.065	54.347
Illiteracy (%)	0.217	0.128	0.221	0.130
Average years of education	5.254	1.356	5.239	1.405
Employment Variables				
Employment (%)	0.557	0.061	0.550	0.059
1st industry (%)	0.749	0.199	0.724	0.206
2nd industry (%)	0.121	0.117	0.125	0.116
3rd industry (%)	0.130	0.089	0.150	0.095
Land Cover Variables				
Forest cover (%)	0.312	0.278	0.415	0.285
Settlement cover (%)	0.046	0.066	0.033	0.089
Agricultural cover (%)	0.394	0.268	0.235	0.206
Grassland cover (%)	0.178	0.209	0.191	0.196
Wetland cover (%)	0.009	0.031	0.017	0.055

See descriptions under Table 2A. Average years of education is calculated using number of people who completed each level of education.

Table 2C: 2000 Summary Statistics

	All (2,261)		>10% PA (316)	
	Mean	Standard Deviation	Mean	Standard Deviation
Basic Characteristics				
Total population	546,709	627,701	406,995	521,413
Total households	149,675	178,006	115,483	157,964
Distance to nearest big city (m)	527.658	739.789	739.355	941.631
Elevation (km)	0.868	1.101	1.234	1.339
Distance to river (m)	562.025	593.917	609.722	663.548
Household Development Index Variables				
Overall index	0.000	0.684	-0.113	0.791
Infant mortality	27.087	23.77	33.493	26.925
Illiteracy (%)	0.094	0.081	0.105	0.103
Average years of education	7.753	1.522	7.683	1.881
Has kitchen (%)	0.794	0.204	0.594	0.296
Has potable water (%)	0.393	0.276	0.406	0.271
Has bath facilities (%)	0.187	0.194	0.188	0.173
Has toilet (%)	0.794	0.204	0.776	0.221
Employment Variables				
Employment (%)	0.762	0.086	0.757	0.096
1st industry (%)	0.711	0.209	0.685	0.215
2nd industry (%)	0.122	0.121	0.117	0.107
3rd industry (%)	0.167	0.108	0.199	0.126
Land Cover Variables				
Forest cover (%)	0.312	0.279	0.376	0.288
Settlement cover (%)	0.051	0.075	0.038	0.085
Agricultural cover (%)	0.393	0.265	0.255	0.219
Grassland cover (%)	0.174	0.209	0.214	0.232
Wetland cover (%)	0.008	0.029	0.017	0.047

See descriptions under Table 2A-B. Dwelling characteristics (kitchen, potable water, bath facilities, toilet) are from the 9.95% census long form.

TABLE 2D: 2010 SUMMARY STATISTICS

	All (2,261)		>10% PA (443)	
	Mean	Standard Deviation	Mean	Standard Deviation
Basic Characteristics				
Total population	586,049	785,988	464,581	805,830
Total households	183,462	280,932	149,534	283,619
Distance to nearest big city (m)	225.376	445.279	379.789	633.225
Elevation (km)	0.868	1.101	1.337	1.399
Distance to river (m)	562.025	593.917	567.030	607.431
HDI Variables				
Overall index	0.041	0.622	-0.026	0.682
Infant mortality	14.249	8.338	16.476	9.208
Illiteracy (%)	0.057	0.057	0.068	0.070
Average years of education	8.965	1.381	8.828	1.715
Healthy senior (%)	0.810	0.065	0.802	0.075
Has toilet in house (%)	0.640	0.239	0.612	0.250
Has hot water (%)	0.422	0.250	0.408	0.242
Has pipes in house (%)	0.563	0.258	0.562	0.275
Has kitchen (%)	0.794	0.192	0.772	0.223
Employment Variables				
Employment (%)	0.712	0.081	0.703	0.088
1st industry (%)	0.596	0.225	0.593	0.225
2nd industry (%)	0.178	0.135	0.153	0.113
3rd industry (%)	0.227	0.125	0.254	0.142
Land Cover Variables				
Forest cover (%)	0.313	0.278	0.361	0.275
Settlement cover (%)	0.059	0.088	0.043	0.096
Agricultural cover (%)	0.385	0.260	0.257	0.218
Grassland cover (%)	0.173	0.208	0.235	0.239
Wetland cover (%)	0.008	0.028	0.014	0.040

See descriptions under Table 2 A-B. Dwelling characteristics are from the 9.95% census long form.

TABLE 3: MAHALANOBIS MATCHING

	Non-treated		Treated		
1982 VARS	Mean	Standard Deviation	Mean	Standard Devaiation	Normalized Difference
Full Sample (N=2,257)		(N=1,129)		(N=1,128)	
Total population	480,958.563	409,592.438	403,259.469	409,592.438	-0.125
GDP per cap.	600.834	624.032	598.399	624.032	-0.003
Illiteracy (share)	0.360	0.145	0.359	0.145	-0.009
Employed (share)	0.515	0.058	0.499	0.058	-0.201
Finished 2nd School (share)	0.163	0.058	0.157	0.058	-0.065
Dist. to river (km)	0.543	0.554	0.581	0.554	0.046
Elevation range (m)	921.664	962.892	1,446.726	962.892	0.360
Elevation mean (m)	721.432	1026.984	1,013.811	1,026.984	0.189
Good Match (N=1360)		(N=472)		(N=888)	
Total population	446,835.813	328,194.938	402,706.594	328,194.938	-0.097
GDP per cap.	499.003	421.275	494.762	421.275	-0.008
Illiteracy (share)	0.360	0.146	0.360	0.146	0.000
Employed (share)	0.502	0.056	0.500	0.056	-0.025
Finished 2nd School (share)	0.156	0.055	0.152	0.055	-0.052
Dist. to river (km)	0.516	0.520	0.531	0.520	0.019
Elevation range (m)	1,046.706	749.604	1,229.970	749.604	0.174
Elevation mean (m)	786.475	1,015.171	848.611	1,015.171	0.043

Treated vs. non-treated groups are created using Mahalanobis matching on the geographic and 1982 socioeconomic covariates shown, plus share in each major ecoregion (not shown). For the purposes of pre-matching, treated groups are counties above the median amount of protected area and untreated are those below the median. Normalized difference is the difference in average covariate values, divided by the square root of the sum of variances for both groups (Imbens and Wooldridge 2009).

TABLE 4. HOUSEHOLD DEVELOPMENT AND EMPLOYMENT OUTCOMES

	(1) Development Index (HDI)	(2) Education Component	(3) Health Component	(4) Employed	(5) Primary Industry	(6) Secondary Industry	(7) Tertiary Industry
Share of county protected	0.152** (0.070)	0.230** (0.114)	0.034 (0.151)	-0.026** (0.012)	-0.015** (0.006)	-0.011 (0.017)	0.026* (0.013)
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend*covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,355	5,355	5,355	5,355	5,355	5,355	5,355
Number of counties	1,360	1,360	1,360	1,360	1,360	1,360	1,360
R^2	0.365	0.346	0.413	0.914	0.709	0.503	0.787

Each column includes county fixed effects, time fixed effects, province trend effects, and interactions between time trends and the following geographic or 1982-level covariates: distance to nearest river, range of elevation, mean elevation, percent of area in each ecoregion, per-capita GDP, middle school education, illiteracy, and total population. Counties are the 1,360 good matches. Columns indicate each of the main dependent variables in the analysis as described in the text. The share of county protected ranges from 0-1 and the percentage employed also ranges from 0-1. Panel regressions with robust, clustered standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

TABLE 5. ROBUSTNESS CHECKS: HOUSEHOLD DEVELOPMENT INDEX

5A. ALTERNATE MAHALANOBIS TREATMENT CUTOFFS

	(1) HDI	(2) HDI	(3) HDI	(4) HDI	(5) HDI
Share of county protected	0.250***	0.152**	0.152**	0.130*	0.129**
	(0.073)	(0.068)	(0.070)	(0.069)	(0.058)
Cutoff (% protected by 2010)	Any protection	1%	Median (1.6%)	2%	4%
Observations	5,944	5,379	5,355	4,887	4,080
Counties	1,508	1,366	1,360	1,241	1,028
R-squared	0.365	0.366	0.365	0.364	0.333

Results for alternate cutoffs used in Mahalanobis matching to determine the control and treatment groups. Column (3) represents the median protection by 2010, and is our main specification (shown in Table 4). All specifications include the same controls as in Table 4 (each column includes county fixed effects, time fixed effects, province trend effects, and interactions between time trends and baseline covariates). Robust clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.10.

5B: ALTERNATE WEIGHTING OF HDI INDEX; ALTERNATE CALIPER SIZES

	(1)	(2)	(3)	(4)	(5)	(6)
	Alternative weights			Alternative calipers		
	Equal Variable Weights HDI	Reweighted HDI (even categories)	Reweighted HDI (no dwelling)	Equal Variable Weights HDI	Equal Variable Weights HDI	Equal Variable Weights HDI
Share of county protected	0.152**	0.101	0.309**	0.178***	0.202***	0.060
	(0.070)	(0.093)	(0.147)	(0.052)	(0.070)	(0.068)
Caliper (SD)	3	3	3	2	2.5	3.5
Observations	5,355	5,355	5,355	4,633	5,025	5,576
Counties	1,360	1,360	1,360	1,174	1,275	1,417
R-squared	0.365	0.414	0.175	0.374	0.373	0.365

Controls are the same as in Tables 4 and 5A. Column (1) is the main index (Table 4), which equally weights all available indicators from each year; it includes dwelling variables (e.g. has kitchen, has pipes) in 2000 and 2010. Column (2) equally weights dwelling, health, and education categories. Column (3) contains only education and health variables. Columns (4) to (6) check robustness to using different caliper sizes in the pre-matching step. Robust, clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.10.

TABLE 6. SUMMARY STATS FOR PROTECTED AREA POLYGONS

Attribute of Protected Area	All Areas	Matched Data	Normalized Difference
Area (m²)	811.408	947.024	0.056
	(10,435.85)	(11,663.62)	
Distance to nearest river (m)	635.937	622.379	-0.064
	(704.03)	(682.86)	
Distance to nearest city in 1990 (m)	930.447	938.956	0.035
	(864.79)	(885.62)	
Mean elevation (km)	886.437	909.045	0.081
	(1,015.45)	(1,049.72)	
Forest cover (%):			
1980	0.469	0.476	0.071
	(0.35)	(0.35)	
1990	0.469	0.476	0.072
	(0.35)	(0.35)	
2000	0.470	0.477	0.070
	(0.35)	(0.35)	
2010	0.467	0.474	0.075
	(0.35)	(0.35)	
Grassland cover (%):			
1980	0.166	0.167	0.018
	(0.23)	(0.23)	
1990	0.165	0.166	0.015
	(0.23)	(0.23)	
2000	0.161	0.163	0.027
	(0.23)	(0.23)	
2010	0.160	0.162	0.031
	(0.23)	(0.23)	
Agricultural cover (%):			
1980	0.247	0.238	-0.113
	(0.27)	(0.26)	
1990	0.246	0.237	-0.116
	(0.27)	(0.26)	
2000	0.247	0.238	-0.114
	(0.26)	(0.26)	
2010	0.243	0.234	-0.116
	(0.26)	(0.25)	
Settlement cover (%):			
1980	0.021	0.020	-0.053
	(0.07)	(0.06)	
1990	0.024	0.023	-0.058
	(0.08)	(0.07)	
2000	0.029	0.027	-0.072
	(0.09)	(0.09)	
2010	0.034	0.032	-0.070
	(0.11)	(0.10)	
Wetland cover (%):			
1980	0.017	0.018	0.028
	(0.074)	(0.076)	
1990	0.016	0.017	0.046
	(0.071)	(0.074)	
2000	0.015	0.016	0.044
	(0.067)	(0.069)	
2010	0.015	0.016	0.049
	(0.065)	(0.068)	

Column 1: all protected area polygons (N=1,960); Column 2: protected area polygons successfully matched with administrative data (N=1,558). Column 3: normalized difference. Standard deviations in parentheses.

TABLE 7. LAND COVER CHANGE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Protected Area-Level					County-Level				
	Forest	Grassland	Agriculture	Wetland	Settlement	Forest	Grassland	Agriculture	Wetland	Settlement
Is protected	0.170	-0.219	0.0699	-0.0663	-0.107					
	(0.129)	(0.136)	(0.152)	(0.0523)	(0.116)					
Share of county protected						-0.0505	-0.227	0.464*	0.0528	-0.248
						(0.126)	(0.235)	(0.250)	(0.185)	(0.218)
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit (county or PA) FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend * covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,820	7,820	7,820	7,820	7,820	5,355	5,355	5,355	5,355	5,355
R^2	0.061	0.072	0.125	0.102	0.128	0.171	0.195	0.483	0.186	0.494
Number of units	1,955	1,955	1,955	1,955	1,955	1,360	1,360	1,360	1,360	1,360

Outcome variables are the inverse hyperbolic sine-transformed percent of each land cover (out of 100). Units of observation for columns 1 to 5 are polygon-years; units of observation for columns 6 to 10 are county-years. “Is protected” is equal to one if the polygon is protected by the time period of the observation. “Share of county protected” ranges from 0 to 1. Each column includes unit fixed effects, time fixed effects, province trend effects; and interactions between time trends and the following geographic or 1982-level covariates: distance to nearest river, range of elevation, mean elevation, percent of area in each ecoregion, per-capita GDP in 1982, middle school education, illiteracy, and total population. Robust, clustered SE in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

TABLE 8. LINEAR COMBINATIONS OF COEFFICIENTS FROM MODELS WITH INTERACTION TERMS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Socioeconomic Variables					Conservation Variables				
	HDI	Employment	Not in Labor force	Primary Industry	Tertiary Industry	Forest Cover	Grassland Cover	Agriculture Cover	Wetland Cover	Settlement Cover
Distance to river (m)										
25% (162.53)	0.158**	-0.029	0.030	0.003	0.025	-0.038	-0.330	1.076***	0.146	-0.719**
50% (395.83)	0.155**	-0.027**	0.020	-0.008	0.026**	-0.046	-0.267	0.701***	0.089	-0.43*
75% (697.5)	0.150**	-0.025	0.005	-0.022	0.026	-0.056	-0.182	0.202	0.013	-0.045
Distance to city (m)										
25% (95.32)	0.210	-0.062	0.027	-0.028	0.051	0.077	-0.721	1.157	-0.003	-0.890*
50% (319.35)	0.170	-0.053	0.024	-0.021	0.043	0.083	-0.688	1.126***	0.014	-0.862**
75% (668.34)	0.107	-0.040	0.019	-0.01	0.029	0.093	-0.635	1.076***	0.04	-0.818**
Mean elevation (km)										
25% (0.17)	0.211*	-0.048	0.032	-0.042	0.05***	-0.007	-0.407	0.441	0.113	-0.180
50% (0.46)	0.195***	-0.042	0.03	-0.035	0.044***	-0.02	-0.360	0.449	0.097	-0.198
75% (1.05)	0.162**	-0.030	0.024	-0.021	0.031***	-0.047	-0.261	0.466*	0.064	-0.237
Population density (per km^2)										
25% (103.81)	0.149*	-0.020	0.010	-0.018	0.018	-0.221	-0.104	-0.038	0.018	0.371
50% (184.65)	0.150**	-0.023*	0.013	-0.016	0.022	-0.138	-0.158	0.209	0.033	0.063
75% (359.76)	0.152**	-0.029**	0.017	-0.013	0.029**	0.043	-0.276	0.750***	0.066	-0.612***
Baseline assets										
25% (-0.42)	0.139**	-0.023**	0.017	-0.013*	0.022*	-0.066	-0.186	0.455*	0.057	-0.249
50% (0.02)	0.207***	-0.037**	0.028	-0.020	0.042**	0.016	-0.396	0.502	0.036	-0.241
75% (0.52)	0.285***	-0.053**	0.040	-0.027	0.064**	0.110	-0.634	0.554	0.013	-0.231
Time period										
0	-0.044	0.023	-0.010	0.045	-0.028	-0.125	-0.072	0.471	1.246	-0.261
1	0.043	0.001	0.000	0.018	-0.004	-0.092	-0.141	0.468*	0.713	-0.255
2	0.131*	-0.021*	0.010	-0.008	0.020	-0.058	-0.210	0.465**	0.180	-0.249
3	0.219***	-0.043***	0.020*	-0.035*	0.044***	-0.025	-0.279	0.462	-0.354	-0.243

Table shows linear combinations of coefficients from regression models where interaction terms are included, evaluated at percentiles. Regressions include county fixed effects, time fixed effects, province trends, and baseline covariates*time trends, the share of county area protected and the interaction between the covariate and share protected. Land cover variables, which are the outcomes for columns (6) to (9), are the inverse hyperbolic sine transformed percentage in each county and range from 0 to 100. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

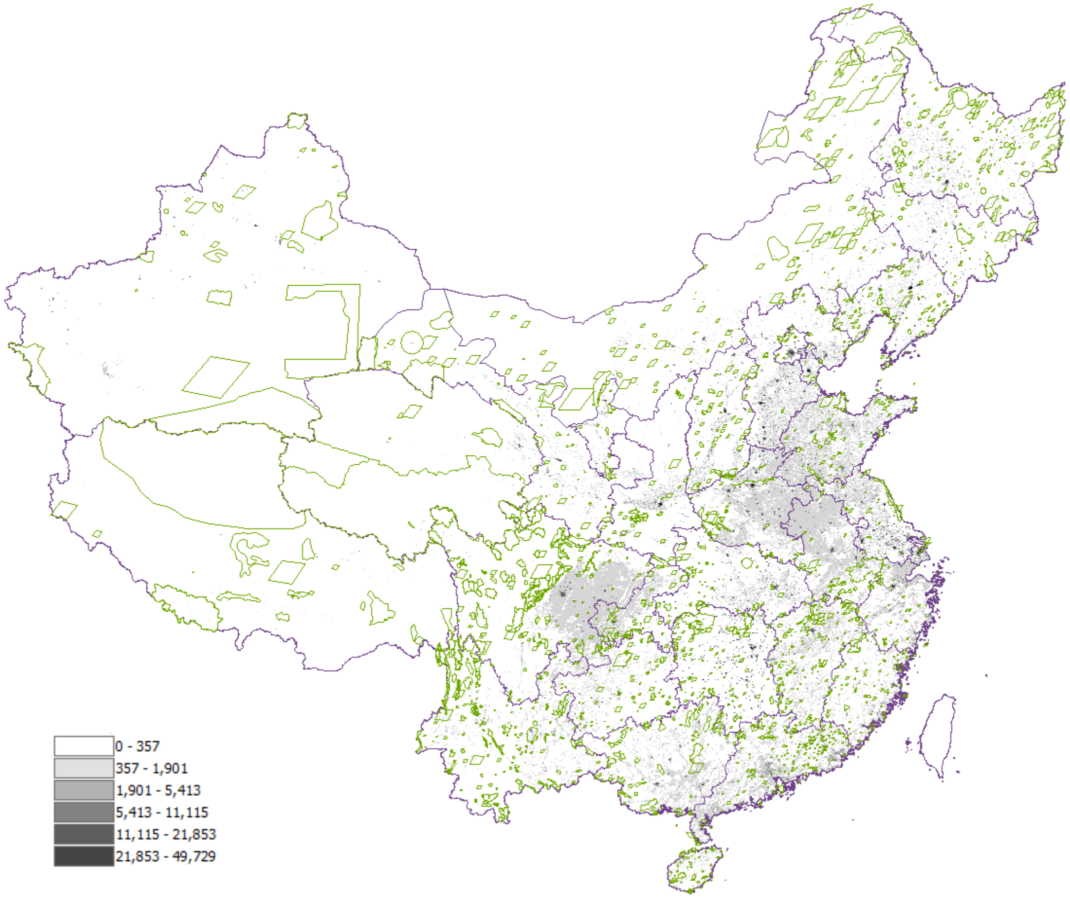
Table 9. Heterogeneity by Administrative Class

Outcome Variable: IHS-Transformed Percent Forest Cover	(1)	(2)	(3)	(4)
Has protection	0.112	0.353*	0.674**	0.279
	(0.168)	(0.184)	(0.344)	(0.171)
Has protection * national level	0.060			
	(0.301)			
Has protection * forest protection goal		-0.376		
		(0.250)		
Has protection * managed by forestry department			-0.740**	
			(0.368)	
Has protection * type of reserve is forest				-0.287
				(0.260)
Polygon FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Province trends	Yes	Yes	Yes	Yes
Time trends * covariates	Yes	Yes	Yes	Yes
Observations	6,216	6,216	6,216	6,216

Outcome variable is the inverse hyperbolic sine-transformed percent forest cover of each protected area and ranges from 0 to 100. Unit of observation is the protected area polygon by year. Has protection is 1 if the polygon is protected by the time period, and 0 if not. Each column includes county fixed effects, time effects, province trend effects, and interactions between time trends and the following geographic or 1982-level covariates: distance to nearest river, range of elevation, mean elevation, percent of area in each ecoregion, per-capita GDP, middle school education, illiteracy, and total population.; Robust, clustered SE in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Appendix A: Appendix Figures and Tables

Figure A1:



Population density data in 2010 (1-km resolution raster) from Wang and Chen (2016). Legend denotes number of persons per km. Green outlines represent Nature Reserves in 2010 from the WDPA dataset; purple outlines are provinces.

TABLE A1. CHECK FOR PRE-TRENDS

Outcome: Share of County Protected (0–1)	(1)	(2)	(3)	(4)	(5)
Lagged HDI	-0.006			-0.008	-0.008
	(0.103)			(0.104)	(0.113)
Lagged population density (per km^2)		0.005		0.007	0.006
		(0.085)		(0.077)	(0.139)
Lagged formal employment			-0.092*	-0.101	-0.098
			(0.050)	(0.108)	(0.318)
Lagged percent primary industry					-0.009
					(1.018)
County FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Time trends * covariates	Yes	Yes	Yes	Yes	Yes
Province trends	Yes	Yes	Yes	Yes	Yes
R^2	0.296	0.295	0.298	0.299	0.299
Observations	2,635	2,635	2,635	2,635	2,635
Counties	1,359	1,359	1,359	1,359	1,359

Regressions of share of county protected in 2000 and 2010 on lagged county characteristics from 1990 and 2000, respectively. Each column includes county fixed effects, time effects, province trend effects, and interactions between time trends and the following geographic or 1982-level covariates: distance to nearest river, range of elevation, mean elevation, percent of area in each ecoregion, per-capita GDP, middle school education, illiteracy, and total population. Robust, clustered standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

TABLE A2. SUMMARY STATISTICS: BIOMES

Biomes	N	Mean	SD	Min	Max
Tropical and subtropical moist broadleaf forests	1,360	0.391	0.479	0	1
Temperate broadleaf and mixed forests	1,360	0.469	0.483	0	1
Temperate coniferous forests	1,360	0.012	0.079	0	1
Temperate grasslands, savannas, and shrublands	1,360	0.033	0.167	0	1
Flooded grasslands and savannas	1,360	0.007	0.072	0	1
Montane grasslands and shrublands	1,360	0.071	0.247	0	1
Deserts and xeric shrublands	1,360	0.016	0.120	0	1

The breakdown of average share of each biome in each county. In analyses, these biomes are consolidated into forest, grassland, and other. Source: WWF 2001.

TABLE A3. HOUSEHOLD DEVELOPMENT AND EMPLOYMENT OUTCOMES (WITH REGION BY YEAR FIXED EFFECTS)

	(1) HDI	(2) Education	(3) Health	(4) Employed	(5) Primary Sector	(6) Secondary Sector	(7) Tertiary Sector
Share of county protected	0.159**	0.233**	0.025	-0.024**	-0.015***	-0.010	0.026*
	(0.069)	(0.115)	(0.152)	(0.011)	(0.003)	(0.017)	(0.014)
R^2	0.39	0.353	0.448	0.92	0.713	0.512	0.787
Observations	5,355	5,355	5,355	5,355	5,355	5,355	5,355
Counties	1,360	1,360	1,360	1,360	1,360	1,360	1,360

Specifications are similar to Table 4, with the addition of region * year fixed effects. Region is based on the classification provided on the UNICEF website (unicef.cn/en/figure-11-geographic-regions-china) which divides the provinces and autonomous regions into three regions: Western, Central, and Eastern. Robust, clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

TABLE A4. HETEROGENEITY BY NATURE RESERVE ADMINISTRATIVE LEVEL

	(1) Forest Cover	(2) Grassland Cover	(3) Agricultural Cover	(4) Wetland Cover	(5) Settlement Cover
Protected * National Nature Reserve	0.160	-0.105	0.071	0.011	-0.111
	(0.259)	(0.398)	(0.275)	(0.119)	(0.253)
Protected * Provincial Nature Reserve	-0.193	-0.173	-0.165	-0.141	0.087
	(0.293)	(0.441)	(0.379)	(0.148)	(0.351)
Protected * City Nature Reserve	0.082	0.050	-0.074	-0.063	0.006
	(0.360)	(0.495)	(0.435)	(0.168)	(0.386)
Protected * County Nature Reserve	0.052	-0.212	0.083	-0.020	-0.138
	(0.437)	(0.599)	(0.363)	(0.143)	(0.290)
Polygon FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Province time trends	Yes	Yes	Yes	Yes	Yes
Time trends * covariates	Yes	Yes	Yes	Yes	Yes
Observations	6,216	6,216	6,216	6,216	6,216

Land cover outcome variables are the inverse hyperbolic sine-transformed percent land cover of each protected area and range from 0 to 100. Unit of observation is the protected area polygon in each year. “Has protection” is 1 if the polygon is protected by the time period, and 0 if not. Each column includes polygon fixed effects, time effects, province trend effects, and interactions between time trends and the following geographic or 1982-level covariates: distance to nearest river, range of elevation, mean elevation, percent of area in each ecoregion, per-capita GDP, middle school education, illiteracy, and total population. Observations are polygon-year, which include 325 national-level reserves, 491 county-level reserves, 532 provincial-level reserves, and 210 city-level reserves. Robust, clustered SE in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Appendix A: Construction of Protected Areas Dataset

Before use, we cleaned the shapefile of 2,173 protected areas. It contained approximately one hundred duplicates of protected areas.[15] We used ArcGIS and projected the data using the Albers Equal Area Conic. We systematically deleted the duplicates with newer establishment dates and kept those with the earliest dates and the same spatial extent (different dates arose when, for example, some dates were date of establishment, and some were the date of international designation, e.g., RAMSAR site status).

After deleting duplicates, many borders were still overlapping due to certain areas receiving different designations at different times and also due to imprecise mapping. The overlapping would have to be removed in order to avoid double-counting areas. To remove overlaps, we cut out all the overlapping areas between multiple parks and systematically removed them from the protected areas that were established at later dates (since the most conservative assumption for the analysis is to count an area as designated after the first possible date) – in other words, if an area "A" (hypothetically established in 1990) shared sliver "C" with area "B" (hypothetically established in 2000), we removed sliver C from area B and kept it in area A. We then merged the remaining ones back with the areas that had not overlapped. The result was a layer of protected areas that retained its identifying information and did not overlap.

To calculate the percent protected area in each supercounty, we created four layers of protected areas: those created before 1982, before 1990, before 2000, and before 2010. We then created unions of each layer with the supercounty layer and created the percent protected area variable by dividing the total supercounty area by the total area of protected area in each county. To measure management types, we combined the protected areas dataset with the government Nature Reserve dataset based on matching names. We first translated the government names into pinyin (alphabetic equivalence of Chinese characters). We began a step-by-step merging of the two layers based on name and province.[16] In total, we were able to match 1,554 protected areas this way, allowing the use of variables regarding target species, management level, and protected area type. These are found to be representative of the full set as of Table 6.

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[15] Many of the duplicates appear to have been created as certain protected areas were elevated to international designations such as UNESCO Man and Biosphere or RAMSAR Wetland (although not all international designations were duplicates).

[16] Spot checks yielded that some of the WDPA entries were incorrect in their stated province but correct in their mapped locations, so we intersected the WDPA layer with a province map to correct about 30 entries for listed province. Next, the matching process continued as follows: first, we matched those whose names perfectly matched. Then, we tried substrings on each dataset of varying lengths (as protected areas in English and Chinese could be denoted in a combination of ways that did not follow a consistent naming tradition: for example, a nature reserve could possibly be named "Xiuwu County Yuntaishan," "Yuntaishan," "Yuntaishan Nature Reserve," "Henan Yuntaishan," "Yuntai Mountain," etc.). Next, we used the fuzzy merge technique to catch matches with typos. Finally, we matched several names through a manual recognition process.