Protected areas reduced poverty in Costa Rica and Thailand

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As global efforts to protect ecosystems expand, the socioeconomic impact of protected areas on neighboring human communities continues to be a source of intense debate. The debate persists because previous studies do not directly measure socioeconomic outcomes and do not use appropriate comparison groups to account for potential confounders. We illustrate an approach using comprehensive national datasets and quasi-experimental matching methods. We estimate impacts of protected area systems on poverty in Costa Rica and Thailand and find that although communities near protected areas are indeed substantially poorer than national averages, an analysis based on comparison with appropriate controls does not support the hypothesis that these differences can be attributed to protected areas. In contrast, the results indicate that the net impact of ecosystem protection was to alleviate poverty.

conservation policy | poverty | empirical evaluation | protected areas | ecosystems

The effect of national parks and reserves on their human neighbors is arguably the most controversial debate in conservation policy (1–9). This debate is particularly contentious in developing nations and has intensified recently as these nations contemplate expanding and strengthening protected area systems under agreements to reduce carbon emissions from deforestation and degradation (REDD) (10). Because ecosystem protection limits agricultural development and exploitation of natural resources (11–14), opposition to protected areas is frequently driven by the assumption that they impose large economic costs and thus exacerbate local poverty (4, 15, 16). However, protected areas can also generate economic benefits by supplying ecosystem services, promoting tourism, and improving infrastructure in remote areas. Net impacts on poverty could thus be positive or negative (1, 2, 8, 17, 18). Recognizing this debate, the 2003 World Congress on Protected Areas' Durban Accord (page 4) urged society to commit "to protected area management that strives to reduce, and in no way exacerbates, poverty" (16).

Assessing empirically whether protected areas have achieved this goal of "do no harm" is difficult. Many studies document high poverty levels and negative community events that are associated with the establishment of protected areas (see references in refs. 19–21). However, these studies do not clearly demonstrate a causal link between protection and poverty because they fail to use direct measures of socioeconomic well-being and to control for confounding effects of geographic and baseline characteristics (5–7, 9, 20). Protected areas are frequently established in remote areas with high poverty rates and low-quality agricultural land (22). To judge whether protected areas are responsible for exacerbating poverty, the appropriate comparison must be between communities living in or near protected areas and communities with similar characteristics and trends that are not affected by protected areas (8, 18, 23).

We achieve this requisite comparison through a quasi-experimental design that improves on previous studies in four significant ways. First, we use poverty measures based on household-level surveys. Household-level data on tangible assets provide the most reliable comparative indicators of human welfare. Second, we analyze impacts at the local scale, which matches the scale at which protected areas are likely to affect communities (see ref. 24 for a discussion on importance of scale). Third, we employ matching methods to select appropriate control communities. These controls are used to answer the central research question: "How different would poverty have been in communities around protected areas in the absence of these areas?" We compare communities heavily affected by protected areas (treated) with similar communities that are less affected by protected areas (controls). Matched control communities are chosen to be similar to treated communities with respect to confounding baseline characteristics that may affect both the placement of protected areas and how poverty changes over time. Matching methods thus ensure that the impacts observed in this study are not due to broader trends in economic growth and poverty reduction, which would affect both treated and control communities. Fourth, our study estimates long-term system-wide impacts, rather than the impacts of a single protected area or small set of protected areas. We study impacts in Costa Rica and Thailand because they are biodiverse developing nations with reliable national statistics and were early adopters of protected area systems, yet they have quite different institutional, economic, and ecological histories.

Poverty Measures and Protected Areas

Our poverty measures are based on national census data of household characteristics and assets (see *Materials and Methods* and *SI Appendix*). In Costa Rica, we use a poverty index (25). In Thailand, we use the poverty headcount ratio, which is the share of the population with monthly household consumption below the poverty line (26). Larger values of both measures imply greater levels of poverty. The unit of analysis for Costa Rica is the census segment (tract), and for Thailand the subdistrict. The outcome of interest is poverty in 2000.

We focus on protected areas created 15 or more years before the poverty outcomes are measured to study longer-term impacts. The treated units are defined as segments and subdistricts with 10% or more of their areas protected by 1985 in Thailand and by 1980 in Costa Rica. We select a 10% threshold because it reflects the call by the fourth World Congress on National Parks and

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Protected Areas to protect 10% of each of the world's major biomes by 2000, and by the Conference of Parties to the Convention on Biological Diversity to conserve 10% of each of the world's ecoregions. The group of available controls, from which matched controls are selected, comprises segments or subdistricts with <1% of their areas protected before 2000.

Constructing Comparison Groups

Globally, the overlap between areas of high poverty and high biodiversity is large (27). In Costa Rica, the mean poverty index in treated (protected) segments was more than five points higher in 2000 than in control (unprotected) segments; a difference greater than one standard deviation. This large difference, however, does not necessarily reflect a causal relationship between poverty and conservation. Segments overlapping with protected areas were already among the poorest segments at baseline (Fig. 1).[3] These baseline differences are important because poverty at baseline and in 2000 are highly correlated ($r = 0.83$). Protected areas were also placed in areas with low geographic potential for economic growth. As shown by Fig. 2, treated subdistricts in Thailand were considerably steeper than control subdistricts. In both countries, treated areas had lower expected land productivity and at baseline were more forested and less accessible to roads and markets (Table S5 and Table S6 of *SI Appendix*).

Spatial overlap between protected areas and low economic potential is a global phenomenon (see references in refs. 11 and 22). A credible analysis must control for confounding baseline characteristics that affect both the placement of protected areas and changes in poverty. We identify potential confounders based on the history of protected area establishment and patterns of economic growth in rural Costa Rica and Thailand. These confounders include preprotection poverty, forest cover, land productivity, and access to transportation and market infrastructure (Table S1 and Table S2 of *SI Appendix*).[4]

To control for these confounders, we use matching methods with bias-adjustment for imperfect matching in finite samples (28). The goal of matching is to ensure the covariate distributions of treated and control units are similar (called covariate balancing), thereby removing observable sources of bias. Matching can be viewed as a way to make the treated and control covariate distributions look similar by reweighting the sample observations (e.g., control units that are poor matches receive a weight of zero). Matching thus mimics experimental design by *ex post* construction of a control group (see *Materials and Methods* for details). For both samples, the covariate balance improves dramatically after matching (Table S5 and Table S6 of *SI Appendix*).

Results

Fig. 3 presents impact estimates for both countries (Table S7 of *SI Appendix* presents estimates in tabular format). The first (dark gray) bar in each panel presents the differences in means of 2000 poverty measures between treated and untreated areas without controlling for baseline differences. The positive signs of the estimates seem to suggest that protection exacerbated poverty.

In contrast, the impact estimates based on matching to control for confounders (lighter bars) indicate that protection reduced poverty. The second bar in the left panel shows that the mean poverty index among Costa Rica's treated segments was ∼1.3 points lower than matched control segments. This estimate implies that ∼10% of the poverty reduction observed in treated segments over time is attributable to protected areas. The second bar in the right panel shows that the mean poverty headcount ratio among treated subdistricts in Thailand was 7.9 percentage points lower than matched control subdistricts. This value corresponds to ∼30% of the counterfactual poverty level, which is represented by the mean poverty headcount ratio for the matched control subdistricts. The third bars in each panel present estimates based on matching using calipers to improve covariate balance. Calipers define a tolerance level for judging the quality of the matches: if available controls are not good matches for a treated unit (i.e., there is no match within the caliper), the unit is eliminated from the sample [see *SI Appendix* (*Methods*) for details]. The estimated impacts on poverty are similar to the estimates generated without calipers.

Another way to indicate the relative magnitudes of the impacts is to normalize the results using effect sizes calculated by dividing the average treatment effect on the treated estimate by standard deviation of the matched control units. For Costa Rica, the estimated effect sizes on the poverty index from matching without and with calipers are −0.20 and −0.22, respectively. For Thailand, the estimated effect sizes on the headcount ratio from matching without and with calipers are −0.43 and −0.30.

Thus, although a simple comparison of mean differences in postprotection poverty suggests that protection exacerbated poverty, there is no evidence of such an impact conditional on baseline characteristics. In fact, the evidence suggests the opposite: protection contributed to poverty alleviation.

Robustness Checks

We conducted a series of robustness checks (see *SI Appendix* for details). As an alternative postmatching model to estimate treatment effects and control for imperfect covariate balance, we estimated postmatching, linear regressions using the matching covariates and extended sets of covariates (Table S10 and Table S11 of *SI Appendix*). We also changed the cut-off date to include all protected areas established before 2000 (Table S15 of *SI Appendix*) and changed the protection threshold defining treatment from 10% to 20% and 50% (Table S16 of *SI Appendix*). The estimated treatment effects are consistently negative and significantly different from zero.

One rival explanation for our results is that protected areas displace poor people into control segments or subdistricts, thereby making protection falsely appear to alleviate poverty. To test this hypothesis, we estimated the effect of protected areas on population (Table S12 of *SI Appendix*). The estimated effects of protection on population density and growth rates are small and statistically indistinguishable from zero ($P > 0.10$), which could be consistent with an emigration story only if the exodus of poor people were matched by a countervailing influx of wealthier people.

Another rival explanation is that protection had negative effects on poverty in nearby control segments or subdistricts. To assess this explanation, we re-estimated the treatment effects after excluding all control units within 10 km of a protected area—i.e., those that might be contaminated by spillovers. We also directly estimated local spillovers by matching control units located within 5 km of a protected area to control units farther away from protected areas. The results do not support the rival spillover explanation (Table S17 of *SI Appendix*): in contrast, the results suggest that if spillovers exist, they are positive, which implies that our estimates are biased toward zero rather than away from zero.

A third rival explanation is that in spite of our efforts to control for observable sources of bias, we may have omitted a confounding variable that is positively correlated with both protection and poverty reduction. Sensitivity analysis examines the degree to which uncertainty about hidden biases in the assignment of protection could alter our conclusions. We use Rosenbaum's (29)

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[3]Most protected areas were created just before or well after 1973, and the 1973 census data allow for construction of a poverty index that is directly comparable to the 2000 index.

[4]Unlike in the Costa Rica case, but similar to the situation in many nations, baseline poverty data for small areas do not exist in Thailand. To control for the baseline state and trend of the poverty outcomes, we use a large set of fixed or pretreatment characteristics that, based on theory and practice, are believed to affect both poverty and protection. We also force the matches to be within the same district to control for unobservable district-level, time-invariant characteristics (see *SI Appendix* for details).

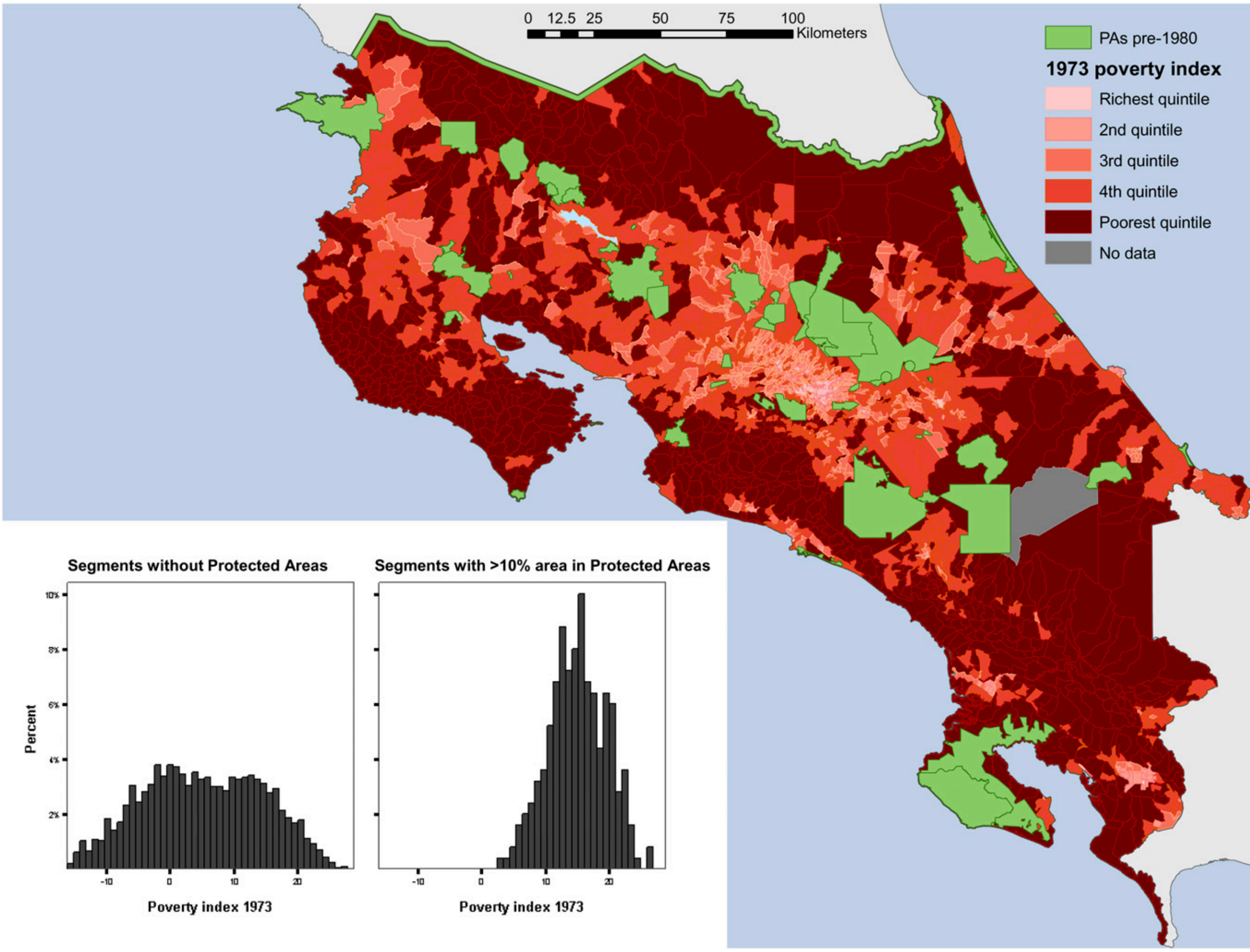

Fig. 1. Costa Rican protected areas established before 1980 were placed in census segments that had baseline poverty indices three times higher than segments without protected areas. The odds of a segment having >10% of its area protected before 1980 are >20 times higher for segments with above-average baseline poverty.

recommended sensitivity test (see *SI Appendix* for details). In both countries, our finding that protection did not exacerbate poverty could change only in the presence of a powerful unobserved confounder, strongly correlated with both protection and poverty alleviation (see Table S8 and Table S9 of *SI Appendix*).

Discussion

Many authors have noted a dearth of empirical evidence in conservation policy (e.g., refs. 23 and 30). Previous studies examine the environmental impacts of protected areas (11–13, 31–37), but one of the most contentious debates in conservation science and policy is the impact of protected areas on the human welfare of neighboring communities. The debate remains contentious because previous studies have failed to use direct measures of human welfare and empirical designs that estimate counterfactual outcomes: how would these communities have fared in the absence of protected areas? Estimating counterfactual poverty levels requires one to control for factors that jointly affect where protected areas are established and the local dynamics of economic growth and poverty. We demonstrate that such control can be obtained by combining available secondary data, which provide objective quantitative measures of poverty and confounders, with statistical methods designed to identify causal relationships. Our study highlights the need for cooperation between groups collecting spatially explicit data on poverty, protected areas, and land-use/land-cover change.[5]

Despite the differences in Costa Rica's and Thailand's institutions, economic development trajectories, and protected area system histories, we find no evidence that their protected areas systems have exacerbated poverty on average in neighboring communities. In fact, we find the opposite: if anything, protected areas have reduced poverty.[6] This result is remarkable given that previous studies have shown that protected area systems in these two nations have reduced deforestation (11, 39). These results thus support recent claims, based on an examination of World Bank project evaluations, that biodiversity conservation is not necessarily incompatible with development goals[7]

[5]For example, the UNEP-WCMC Vision 2020 project seeks to expand the World Database on Protected Areas to socioeconomic issues as well as develop indicators related to protected areas and social impacts.

[6]Our results, which focus on changes in poverty, do not call into question the widely held belief that many of the benefits of biodiversity protection are enjoyed by residents far from protected areas while many of the costs are incurred by local people (38).

[7]Although our conclusion that protected areas reduce poverty appears to be consistent with the results of Wittemyer et al. (9), they use population growth as a proxy for socioeconomic benefits. In our study, population, whether measured as densities or as growth rates, was not significantly affected by protected areas in either nation (see *SI Appendix* for details). In Costa Rica, if one did not control for confounding factors in estimating the population impact of protection, one would have erroneously inferred that protection caused a significant population increase.

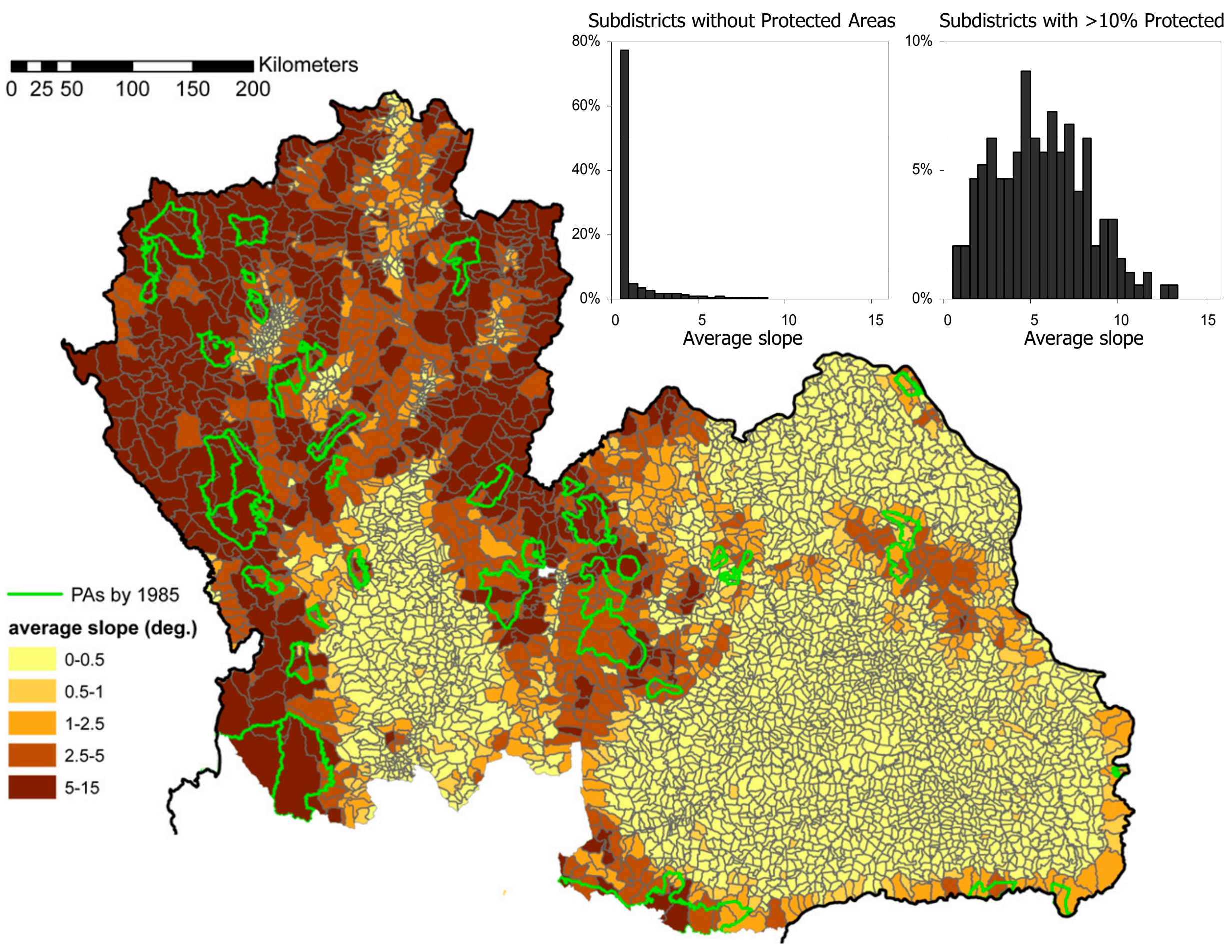

Fig. 2. Protected areas in North and Northeast Thailand established before 1985 were placed in subdistricts with land more than five times steeper than land in subdistricts without protected areas. Much of this targeting was designed to protect important upper watershed areas.

(40). Our results also suggest that protecting biodiversity can contribute to both environmental sustainability and poverty alleviation, two of the United Nations Millennium Development Goals (41, 42).

Several caveats should be emphasized. First, we measure the average net impact of protected areas on poverty. Our results do not imply that all segments, subdistricts or poor households experienced poverty alleviation from protected areas. Second, we measure the impact of protected areas over decades. Short-term impacts may differ. Third, our measures of poverty are based on a limited set of material dimensions and do not capture all dimensions of social welfare (43) (e.g., hard-to-measure aspects such as "feeling in control of one's life" or "ability to maintain cultural traditions"). Future collaborative evaluations among anthropologists and economists could explore other dimensions (44). Finally, our analysis does not elucidate the specific mechanisms through which protected areas may have reduced poverty. We speculate that benefits to local residents have included tourism business opportunities, investments in human and physical capital by national and international agents, and the maintenance of ecosystem services (39, 45, 46). Research to understand these mechanisms is a clear future priority.

Finally, Costa Rica and Thailand are not representative of all developing nations. They have both experienced rapid macroeconomic growth (47, 48), have had relatively stable political systems, have made substantial investments in their protected area systems, and have relatively successful eco-tourism sectors. Thus whether our results would hold for other nations is an open question. Our study can, and should be, replicated in other nations, as well as extended to include a variety of land governance regimes (e.g., indigenous reserves) and explorations of the ways in which impacts vary based on observable covariates and protected area management status (49). Only through multination replications and extensions can we obtain a global picture of the impacts of protected areas on human welfare.

Materials and Methods

For more details on data and methods, see *SI Appendix* and Tables S1–S4.

Data. For Costa Rica, we use data from the population and housing censuses conducted by the Instituto Nacional de Estadistica y Censos (INEC) in 1973 and 2000. Digitized GIS census segment boundaries for 1973 and 2000 were provided by the Cartography Department at INEC. GIS data layers for forest cover in 1960 (11), protected areas (source: National System of Conservation Area Office, Ministry of Environment and Energy, 2006), and the locations of major cities were provided by the Earth Observation Systems Laboratory, University of Alberta, Canada. Other GIS layers are land use capacity (source: Ministry of Agriculture) and roads digitized from hard copy maps for 1969 (source: Instituto Geográfico Nacional, Ministerio Obras Publicas y Transporte). The poverty index builds on recent efforts to develop a census-based poverty index for Costa Rica (25). Summary statistics of the data are presented in Table S1 of *SI Appendix*.

For Thailand, we use data from a poverty mapping analysis (26) which combines data from the Thai Socio-Economic Survey 2000, the Thai Population and Housing Census 2000, and the 1999 Village Survey. Instead of the poverty headcount ratio used in the main text, one could also use the poverty gap, which measures the mean distance between household consumption and the poverty line. Using the gap yields the same conclusions (Table S7 of *SI Appendix*). Protected area boundaries are from the IUCN

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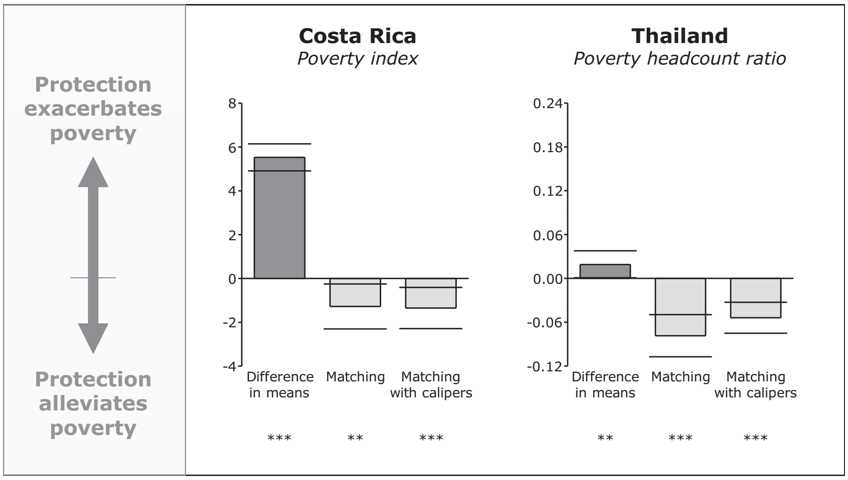

Fig. 3. Do protected area systems exacerbate poverty? Poverty rates in 2000 were, on average, higher near Costa Rica and Thailand protected areas, seemingly suggesting that protected area systems have exacerbated poverty (dark bars). However, estimates using matching methods to control for differences in baseline characteristics that affect both poverty and the location of protected areas indicate that protected areas have alleviated poverty (lighter bars). Bars refer to 95% confidence intervals. Standard errors for matching estimates were calculated using the robust variance formula in ref. 27. A *t* test is used to assess the difference in means between treated and control units. Asterisks refer to tests of the null hypothesis of zero impact (**, $P < 0.05$; ***, $P < 0.01$). Costa Rica sample: *N* treated = 249; *N* control = 4164; *N* treated dropped by calipers = 22. Thailand sample: *N* treated = 192; *N* control = 3479; *N* treated dropped by calipers = 48.

World Database of Protected Areas (Thailand country dataset supplied by ARCBC-ASEAN). Years of establishment for protected areas from this database were cross-checked with information from Thailand's Department of National Parks. Sources of geographic data and summary statistics are presented in Table S2 of *SI Appendix*.

The units of analysis, poverty measures, and covariates are described in the main text, and further details, including the methods for deriving the poverty measures and the motivation for selecting covariates, are provided in *SI Appendix*.

Methods. We use matching methods to estimate the effect of protected areas on poverty in communities near protected areas: the Average Treatment Effect on the Treated (see *SI Appendix* for details). Matching was done in R (50). We selected the matching method that produced the best covariate balance with each country sample (51). For Costa Rica, we chose covariate matching that uses the Mahalanobis distance metric. For Thailand, we chose nearest-neighbor propensity score matching with exact matching on district. All matching is one-to-one with replacement: each treated unit is matched to one control unit. Based on recent work that demonstrates that bootstrapping standard errors is invalid with nonsmooth, nearest-neighbor matching with replacement (52), we use Abadie and Imbens' variance formula whose asymptotic properties are well understood (28). We use the version that is robust to heteroskedasticity. We use a postmatching bias-correction procedure that asymptotically removes the conditional bias in finite samples (28). For caliper matching, we define the caliper as one standard deviation of each matching covariate.

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