Navigating Conservation Seas: Estimating Marine Protected Areas Effectiveness and Unveiling the Intricacies of Industrial Fishing Behavior

Jorge Luis Montero Mestre

Universidad de los Andes
Colombia

February 8, 2024

Deutscher Akademischer Austauschdienst
German Academic Exchange Service

The SDG nexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Overview

- **Question:** Are industrial fishing vessels deterred by marine protected areas?
- **Approach:** A non-parametric spatial RD identification strategy. Exploiting the spatial discontinuity of the MPA boundary and the variation of the distance to it.
- **Goal:** Quantify the effect of Marine Protected Areas as conservation instrument on industrial fishing activity.

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDG nexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Agenda

The SDG[nexus] Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Motivation

Why Should We Care About the Fishing Sector and Marine Resources?

1. **According to FAO (2020), more than three billion people depend on marine resources.**
    - 38.98 million people worldwide depend on fishing for their livelihood.
    - Fish consumption equivalent to 20.3 kg/year per person.
        - The fish trade is estimated at 168 trillion dollars (2018).
        - 11% of total agricultural trade.
2. **Additionally, oceans absorb 40% of emitted carbon dioxide in the atmosphere (DeVries et al., 2017).**
3. **However, overfishing jeopardizes ecosystem sustainability and economic stability (FAO, 2020).**
    - 34.6% of fishing occurs outside sustainability standards.
    - The cost of overfishing is estimated at 32 trillion dollars.
    - The total value of current Illegal, Unreported and Unregulated (IUU) fishing losses worldwide are between $10 bn and $23.5 bn annually (Agnew et al., 2009)

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

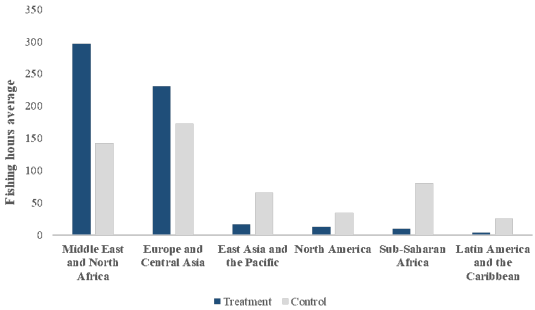
Motivation

Marine Protected Areas and fishing compliance

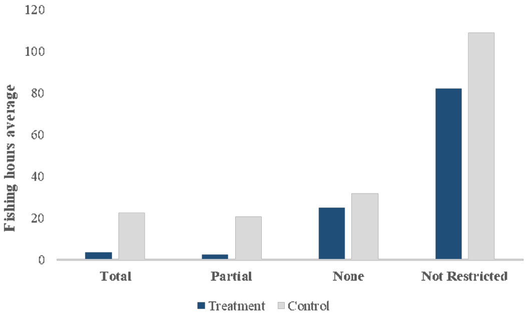
1. Marine Protected Areas (MPAs) are a widely used control tool for fishing overexploitation around the world. **Nevertheless, what we know about its effectiveness is limited.**
2. A Marine Protected Area is an area with geographical delimitation within which limits are imposed on environmental exploitation activities. **About 7% of the oceans are protected.** ◂ Table
3. **Industrial/commercial fishing is prohibited in all MPAs**. No comply with the regulations imposed on the MPAs generates fines and sanctions in case of being caught.
4. Although the delimitation of the MPAs is not physically visible, it is known to the vessels through the geographic location systems (GPS).
5. **The greater restriction designation, according to the categories of MPAs, necessarily implies a greater commitment to monitoring and control.**

SDG nexus network | JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN | DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service | The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Fishing is still detected within the MPAs



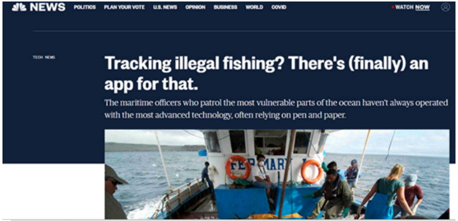
(a)



(b)

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDG[nexus] Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

What role does monitoring play?

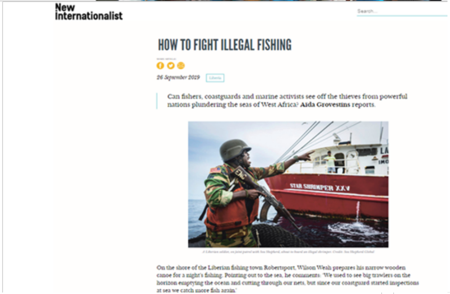


NEWS POLITICS PLAN YOUR VOTE U.S. NEWS OPINION BUSINESS WORLD COVID WATCH NOW

TECH NEWS

Tracking illegal fishing? There's (finally) an app for that.

The maritime officers who patrol the most vulnerable parts of the ocean haven't always operated with the most advanced technology, often relying on pen and paper.



New Internationalist

HOW TO FIGHT ILLEGAL FISHING

26 September 2019 Liberia

Can fishers, coastguards and marine activists see off the thieves from powerful nations plundering the seas of West Africa? **Aida Grovestins** reports.

A Liberian soldier, on joint patrol with Sea Shepherd, about to board an illegal shrimper. Credit: Sea Shepherd Global

On the shore of the Liberian fishing town Robertsport, Wilson Weah prepares his narrow wooden canoe for a night's fishing. Pointing out to the sea, he comments: 'We used to see big trawlers on the horizon emptying the ocean and cutting through our nets, but since our coastguard started inspections at sea we catch more fish again.'

Research questions

Are industrial fishing vessels deterred by marine protected areas?

Q1: **To what extent have marine protected areas decreased fishing efforts within their borders?**

- quantify and analyze the effect.

Q2: **What is the behavior of industrial fishing vessels around marine protected areas?**

- analyze the effect.

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

What does the theory tell us?

Enforcement levels and economic incentives

Following the model proposed by Charles et al. (1999):

- The choice of fishing locations by vessels will primarily be influenced by the fishing cost and the biomass of available fish.
- The decision to engage in fishing at a particular location will be determined by the likelihood of achieving a higher catch, which could be greater in areas where fishing is prohibited (e.g., Marine Protected Areas or EEZ).
- Subsequently, unauthorized fishing will arise when enforcement measures are not sufficiently robust to deter incentives for engaging in Illegal, Unreported, and Unregulated (IUU) activities. Moreover, unauthorized fishing will persist if the expenses associated with avoidance tactics are not prohibitively high and are also highly effective.

If the levels of enforcement and monitoring are not strong enough, economic incentives will lead to vessels violating the restrictions imposed on the MPAs.

SDG nexus network JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service The SDG nexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Contribution

What do I find?

Q1

- On average, industrial fishing efforts have been reduced within MPAs by 30.5% of the total fishing hours per km^2 that were carried out in the world between 2016 - 2020.
- Fishing efforts have been reduced primarily in those protected areas with a stricter protection designation.

Q2

- **I find evidence of a strategic behavior of the vessels around the border of the MPAs, which depends on MPA protection levels.**

I contribute to the literature on the effectiveness of environmental policy instruments in the maritime sector (Ahmadia et al., 2015; Gill et al., 2017; Harasti et al.; 2019, Davis and Harasti, 2020).

1. I provide greater representativeness in the evaluation of the effectiveness of the MPAs.
2. I identify **causal effects** of **MPAs** on the **behavior of industrial fishing activity** at a global level.

SDG nexus network | JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN | DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service | The SDG nexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Data and empirical strategy

The SDG^{nexus} Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Data

Fishing Activity ▸ Scheme

- Global Fishing Watch: Automatic Identification System (AIS) and Vessel Monitoring Systems (VMS) (Englander, 2019; Kroodsma et al., 2018).
  - It is measured in number of hours of fishing activity with a resolution of 0.1 degrees.
  - The fishing activity that is captured is **industrial** at a global level.
  - It is used for the years 2016 - 2020.

Marine Protected Areas ▸ Map

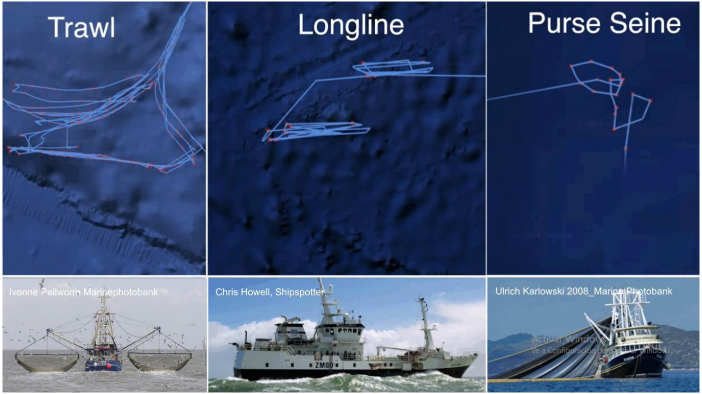
- World Database Protected Areas: Contains information on the characteristics of the MPAs in the world.
  - 434 marine protected areas
  - 47 (total protection), 60 (Partial protection), 49 (multipurpose) y 278 (Not Reported).

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Global Fishing Watch: Monitoring System

Back

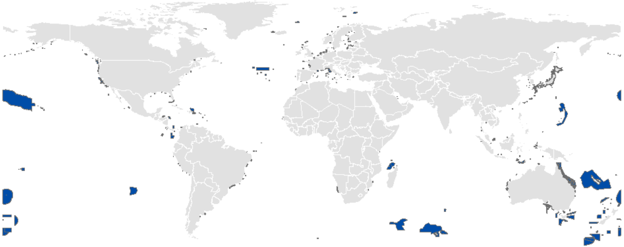
Global Fishing Watch: Monitoring System



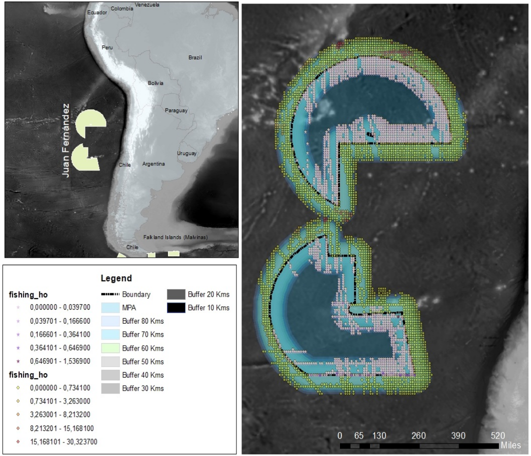
Back

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Conservation and fishing efforts



Empirical Framework
Identification



Empirical Framework

Spatial Regression discontinuity (Calonico et al., 2014)

$$Y_{ji} = \alpha + \tau_{RD_0} D_{ji} + \sum_{k=1}^{k} \beta_k X_{ji}^k + D_{ji} \sum_{k=1}^{k} \gamma_k X_{ji}^k + \Gamma_{ji} + \theta_j + \mu_{ji} \tag{1}$$

Where Y_{ji} denotes the fishing effort, measured by the number of hours of activity, at a given pixel, denoted by i, at MPA j. D_{ji} is an indicative variable that takes the value of 1 if the observation is inside the MPA or 0 if it is outside. The variable X_{ji} indicates the minimum distance to the MPA border by the cells. Controls such as depth, distance to the coast and phytoplankton concentration Γ_{ji} are included, and it is also controlled by a polynomial of order k of the distance to the MPA border. Finally, fixed effects per MPA and region θ_j are added.

The parameter of interest is τ_{RD_0} which captures the **total average effect of MPAs on the number of hours of fishing activity** in the period 2016 - 2020.

Identification

Assumptions

- Treatment assignment is exogenous.
- **Continuity of covariates at the cutoff point** (Canay & Kamat, 2018).
  - Depth
  - Phytoplankton concentration
  - Distance to the coast
- Independence among the treated and control groups.
- No manipulation of the assignment rule.

Permutation test Figures

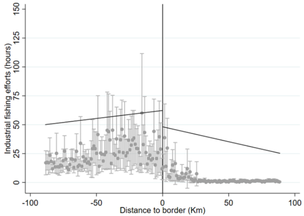
The SDG[nexus] Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Results

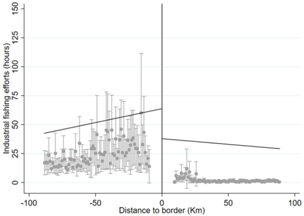
The SDG[nexus] Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Main Results

Average effect of marine protected areas



Q2: All obs.



Q1: Donut hole

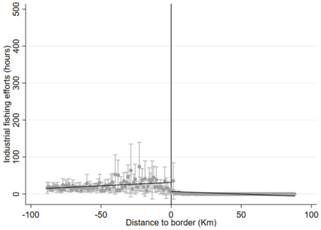
	All Obs.		**Donut Hole**	
	Optimal	**80kms**	**Optimal**	**80kms**
	(1)	**(2)**	**(3)**	**(4)**
MPAs	0.26	-7.69**	-10.8**	-14.9***
	(5.73)	(3.19)	(4.30)	(3.42)
Mean (Yi)	27.2	23.8	26.8	23.9
Bandwidth	26.05	80	61.09	80
% of mean	0.9	32.3	40.3	62.3
Observations	39673	39673	35263	35263

▸ Robustness checks

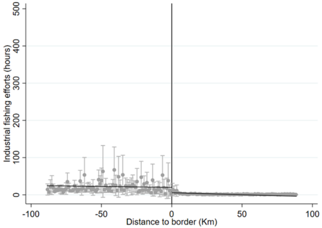
SDG nexus network · JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN · DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service · The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Main results

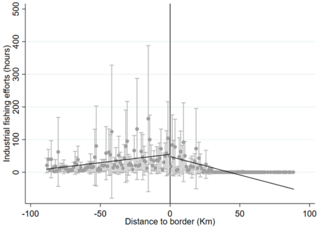
Restriction levels and conservation objectives



Total



Partial



None

	Total Restriction (1)	**Partial Restriction (2)**	**No Restriction (3)**	**Not Reported (4)**
MPAs	-13.22***	-10.46***	11.98	85.42***
	(5.05)	(3.20)	(23.28)	(19.9)
Mean (Yi)	23.1	21.33	31.56	110.6
Bandwidth	80	80	80	80
% of mean	57.2	49	37.9	77.2
Observations	11654	23491	4528	39764

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITAT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDG nexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Discussion & future research

1. Beyond the reductions in fishing efforts, MPAs could be contributing to the displacement and greater diffusion of fishing activity. **Good or bad?** (ABPmer, 2017).
2. The results seem to indicate that the lower level of restriction in the designation of MPAs generates incentives to not comply with the MPA regulations. **What happens in the extensive margin?** (Gill et al., 2017).
3. Conservation efforts must be reinforced and be made homogeneous through all MPAs in the world. **Not more MPAs, but better MPAs**. **Cost-benefit analysis?**
4. Although there is a clear use of **positive spillovers**, there is also evidence of their abuse (**negative spillover**). **What is the net result?** $\Rightarrow Y_{it} - Y_{it}$.

The SDG[nexus] Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Thank you

jl.montero@uniandes.edu.co
My Webpage

The SDG^{nexus} Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Coverage of Marine Protected Areas

Table A1: Coverage of marine protected areas 2010 - 2020

	2010		2020	
	No.	*Coverage (km^2)*	*No.*	*Coverage (km^2)*
A. Regions				
East Asia and the Pacific	99	1.432.023	153	3.021.285
Europe and Central Asia	81	76.043	115	215.248
Latin America and the Caribbean	42	279.514	47	331.012
Middle East and North Africa	4	560	5	1124
North America	57	1.949.358	70	1.953.872
Sub-Saharan Africa	9	16.718	9	16.718
B. Protection Designation *"No Take"*				
Total (%)	31	725.479 (100%)	47	725.118 (100%)
Partial (%)	54	1.317.552 (46.8%)	60	1.377.580 (32.8%)
None	34	312.250 (0%)	42	347.782 (0%)
Not Reported	187	1.497.332 (0%)	264	1.815.278 (0%)

Back

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Identification

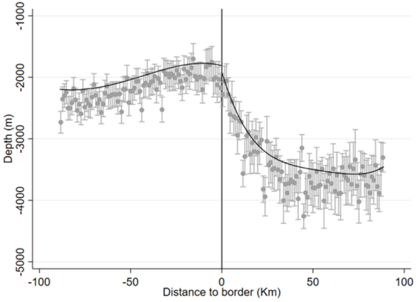
Table A2: Continuous distribution of baseline ocean characteristics at MPAs borders by "*no-take*" restriction level

	Treatment		Control		Permutation test	
	Mean	**Standard Deviation**	**Media**	**Standard Deviation**	**t-Test**	**p-value**
A. Total						
Depth (m)	-2789	1913	-1223	1641	0.01	0.8
Phytoplankton Concentration Index	144.03	37.24	136.4	47.65	0.05	0.22
Distance to the coast (km)	367	300.8	155.9	250.7	0.02	0.57
B. Partial						
Depth (m)	-3443	1629	-3110	1861	0.27	0.00***
Phytoplankton Concentration Index	124.6	54.6	124.9	52.44	0.05	0.18
Distance to the coast (km)	483.8	417.8	442.6	401.6	0.03	0.34
C. None						
Depth (m)	-3484	2736	-2114	2229	0.09	0.06
Phytoplankton Concentration Index	123.3	60.46	141.8	52.91	0.06	0.12
Distance to the coast (km)	284.6	254	140.8	170.9	0.13	0.02**
D. Not Reported						
Depth (m)	-2316	2127	-1360	1507	0.16	0.00***
Phytoplankton Concentration Index	124.1	48.86	132.6	51.93	0.14	0.01**
Distance to the coast (km)	277.1	266.7	144.4	206.6	0.34	0.00***

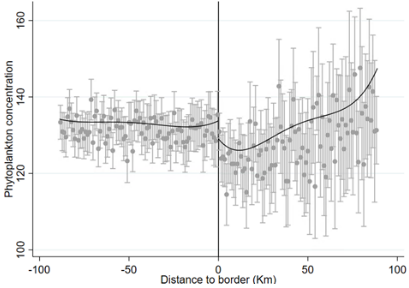
Source: Own calculations with NOAA database. Note: * $p<.10$, * $p<.05$, ** $p<.01$. The first two columns present the descriptive statistics of the observations within the 88 km buffer around the border of the MPAs. The last two columns show the results of the continuous distribution test of the covariates proposed by Canay & Kamat (2018) with 1,000 permutations. **The null hypothesis is that there is continuity of the baseline covariates at the cutoff point.**

Back

Identification



(a)



(b)

Figure A1: Depth and productivity in MPAs. Note: Observations are clustered at 1-km intervals and smoothed with a covariate-adjusted linear polynomial. The observations to the left of the cut-off point are those that are outside the protected area, while those to the right are those that are inside. The bars represent the confidence intervals at the 95% confidence level. Panel (a) Depth, and (b) Phytoplankton concentration.

◂ Back

The SDG^{nexus} Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Robustness check

Placebo test

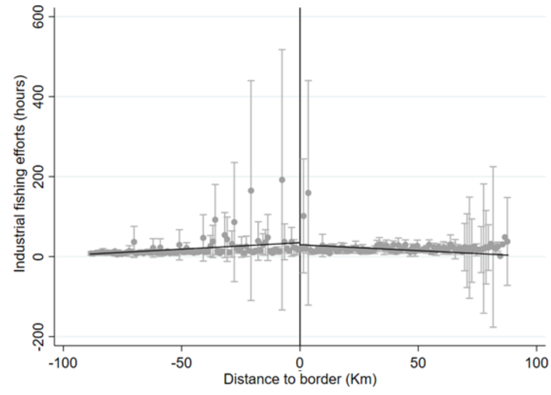


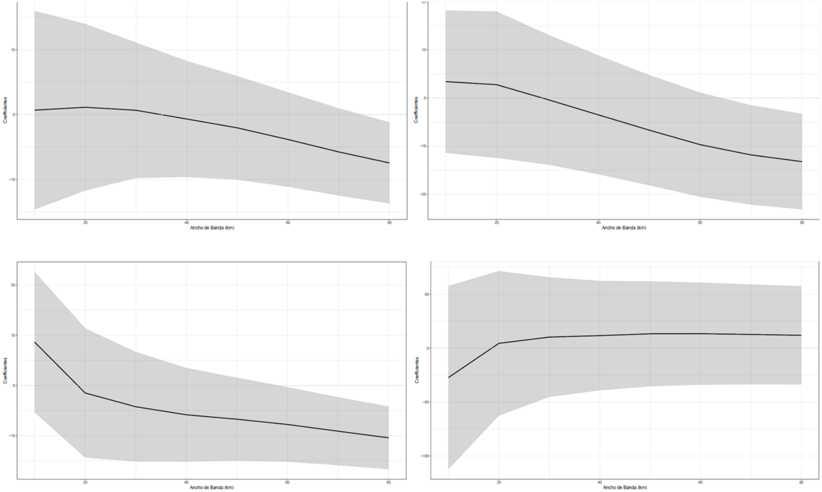
Figure A2: Effects of MPAs on fishing effort for MPAs created in 2020. Note: Placebo test for pre-treatment. Observations are clustered at 1-km intervals and smoothed with a covariate-adjusted linear polynomial. The observations to the left of the cut-off point are those that are outside the protected area, while those to the right are those that are inside. The bars represent the confidence intervals at the 95% confidence level.

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDG nexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).

Back

Robustness check

Bandwidth sensitivity test



Back

SDG nexus network
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service
The SDGnexus Network, supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ).