Unveiling the Dynamic Impact of Protected Areas: An Event Study Analysis to Assess Conservation Effectiveness

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Abstract

Previous studies estimating the effect of the creation of protected areas (PAs) on ecosystem conservation suffer from biases due to staggered protection and to unobservable drivers of protection's effectiveness. We address these biases by using a cohort-time refined effect estimator in an event study with Amazon Basin data from 2003 to 2020. We also unveil meaningful dynamic patterns that remained so far hidden in previous papers' aggregate effects. Our findings show that PAs' effect on deforestation was halved by the aforementioned biases, being also deflated in 13% by the failure to control for concomitant anti-deforestation policies. We also found evidence of forward-looking behavior by deforesters, with internal deforestation increasing two years before protection. Effects were also heterogeneous. Whereas both moderately and severely restricted PAs avoided fires, only severely restricted avoided deforestation. Finally, whereas conservation unit PAs have not reduced deforestation, national units reduced fires but subnational increased them. Indigenous lands reduced deforestation and fires.

Introduction

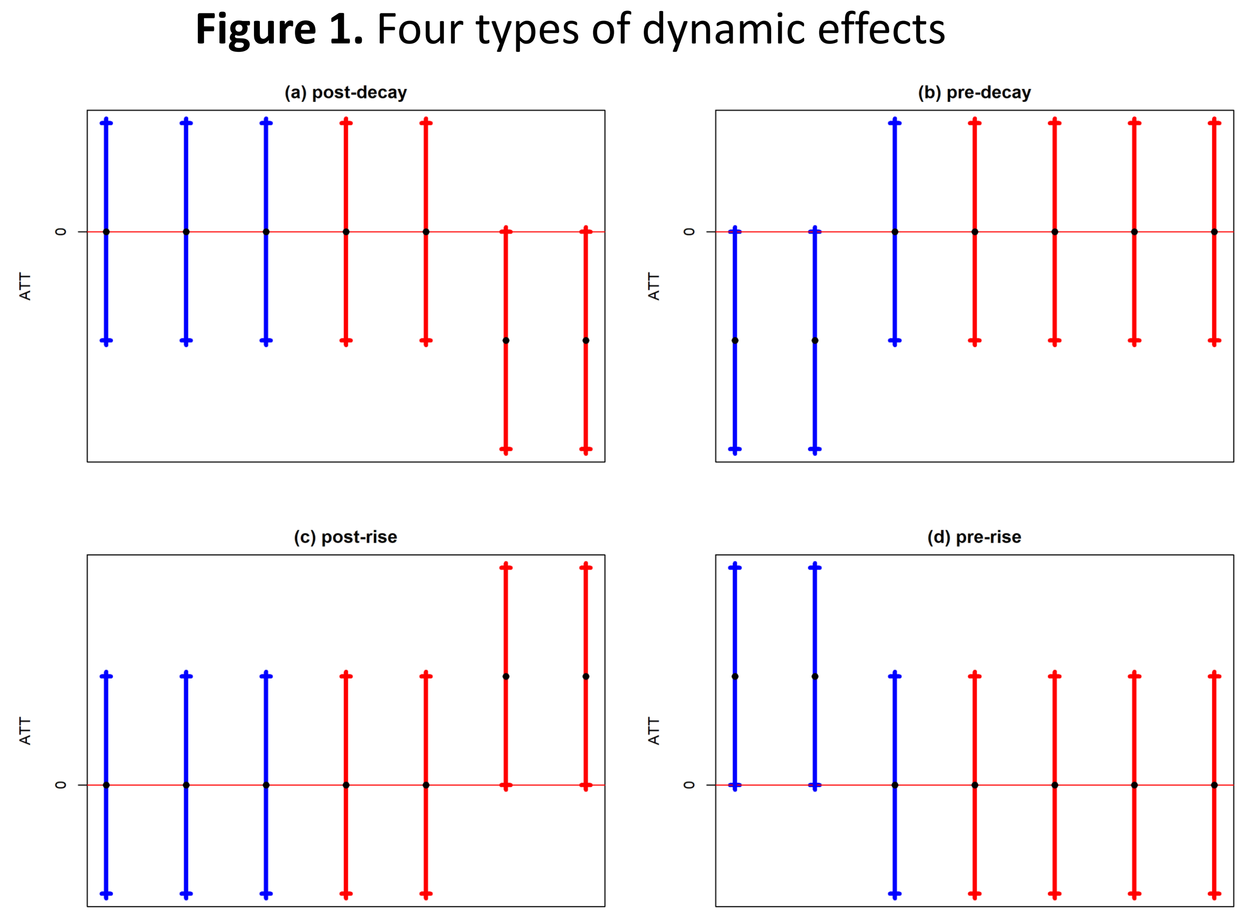
Protected areas (PAs) have proven effective in conserving natural capital, such as forests and wetlands, by preventing deforestation, fires, and associated carbon emissions, while also increasing biodiversity and reducing poverty. However, the cost-effectiveness of PAs varies depending on local and time-specific factors. Existing research on PAs often suffers from biases due to unobservable drivers of effectiveness and staggered creation of PAs over time.

To address these inaccuracies, we introduce a new methodological procedure combining matching and cohort-time refined differences-in-differences (DiD) estimator. The event-study unveils the dynamics of PAs' effects, particularly delays and anticipations in deforestation changes relative to the introduction of protection. These are shown to be theoretically consistent with a forward-looking behavior by deforesters. An heterogeneity analysis provides insights into the specific impacts of different PA types.

The importance of explicitly controlling for confounding environmental policy is demonstrated with reliance on anti-deforestation policy proxies. The bias avoided is further proof that the "pure-matching" approach dominating PA literature is inaccurate.

Our combined approach is therefore a more reliable source of prescriptions about the allocation of public funds to protected areas and competing environmental interventions.

Figure 1. Four types of dynamic effects



Methods and Materials

Three main identification challenges are faced: (i) self-selection of the site to be protected, (ii) staggered creation of PAs over time and potential cohort-specific effects and (iii) confounding concurrent changes. To mitigate associated biases, matching was used in the first step to increase balance and the common extent of support between treated and untreated (control) observations. Secondly, we implemented the group-time differences-in-differences approach developed by Callaway & Sant'Anna (2021) using covariates and fixed effects to estimate the average treatment effect on the treated (ATT). Cohorts contributing for non-parallel trends in the whole matched sample event-study were excluded (figure 2). The two-step approach allows to deal with self-selection on covariates, omitted time-variant and invariant confounders, as well as to accurately calculate the PAs' overall effect by appropriately accounting for group (cohort) heterogeneities.

The following equation was estimated by spatial units (*i = pixels*) using Y = (*Deforestation,Fires*):

$$Y_{it} = \gamma + \delta PA_{it} + X_{it}\Gamma + a_i + \lambda_t + u_{it} \qquad i = 1,\dots,N,\ t = 2003,\dots,2020$$

Results

The PA effect estimation approach adopted in most previous studies is subjected to three sources of biases: (1) failure to conduct post-matching DiD, (2) failure to account for staggered protection and, (3) failure to control for concurrent policies.

Table 1. Biases from naïve estimation, relative [and absolute]

	Deforestation	Fires
"Matching alone" bias	-73 % [-1.84%]	-4 % [-0.26%]
Staggered protection bias	-50 % [-1.26%]	-91 % [-5.49%]
Concurrent policy bias	-13 % [-0.42%]	16 % [0.86%]

A pre-protection rise in deforestation was observed two years before PA creation. An evidence of forward-looking behavior by deforesters.

The post-treatment effects exhibited a gradual magnification pattern, indicating that enforcement staff take time to improve their performance.

Figure 2. Event studies with all groups and all PAs

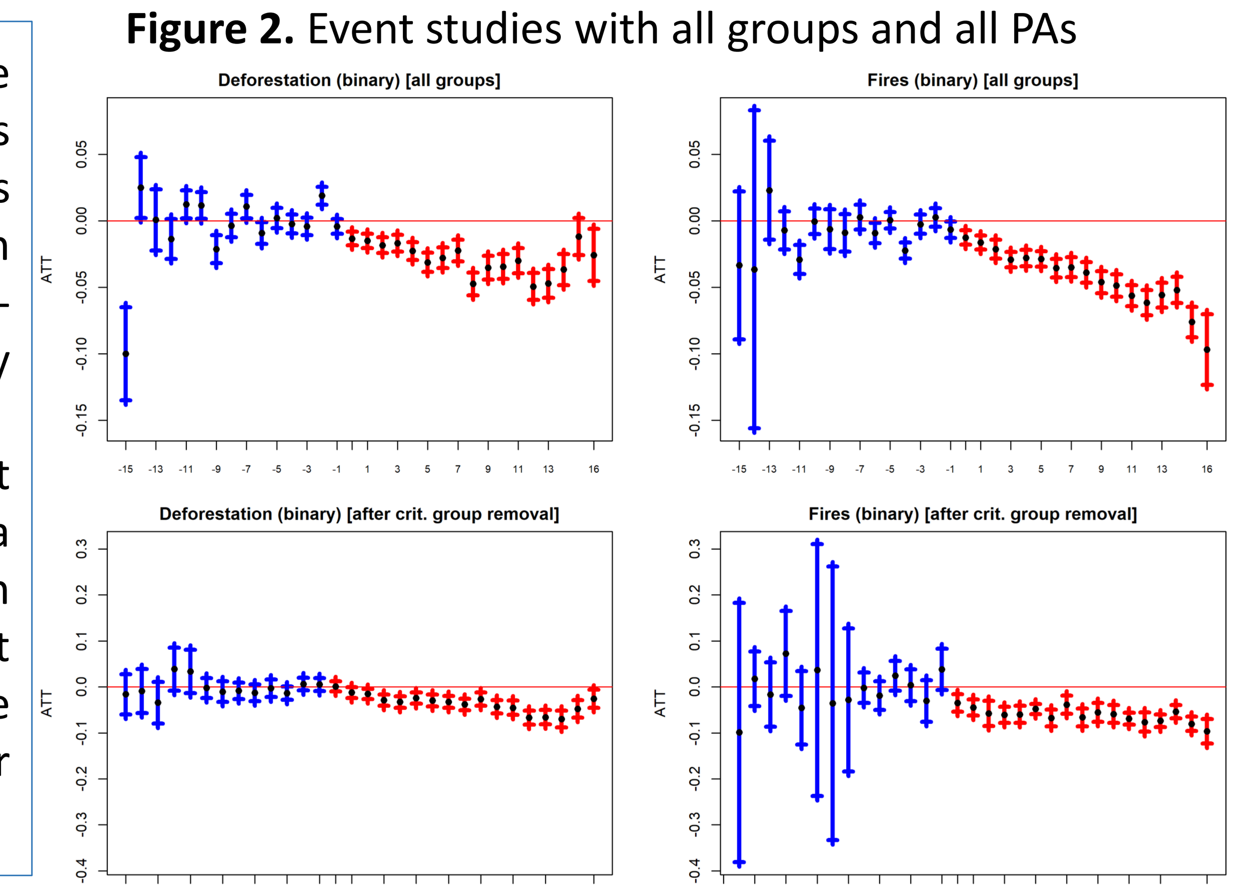


Table 2. Average Impact by type, Deforestation

			Group-time staggered DID							
	Matching only	Non-staggered DID-FE	All protected areas, Amazon Basin	Only indigenous lands, Amazon Basin	Only subnational conservation units, Amazon Basin	Only national conservation units, Amazon Basin	Only indirect conservation units, Amazon Basin	Only direct conservation units, Amazon Basin	All protected areas, without institutional covariates, Brazilian Amazon	All protected areas, with institutional covariates, Brazilian Amazon
ATT	-0.0067***	-0.0124***	-0.025*	-0.0243***	0.0022	-0.0113	-0.0227*	-0.0028	-0.0279***	-0.032***
SE	(0.0013)	(0.0016)	(0.0037)	(0.0066)	(0.0095)	(0.0071)	(0.0093)	(0.0059)	(0.0068)	(0.0053)
N	594,702	594,702	415,080	106,830	57,762	88,038	84,366	141,948	145,224	241,074
Clusters		33,039	23,060	5,935	3,209	4,891	4,687	7,886	8,068	13,393

For fires, there is a strong impact of national PAs on containing fires. Both moderately (indirect conservation units) and severely (direct conservation units) restricted PAs avoided fires.

Table 3. Average Impact by type, Fires

			Group-time staggered DID							
	Matching only	Non-staggered DID-FE	All protected areas, Amazon Basin	Only indigenous lands, Amazon Basin	Only subnational conservation units, Amazon Basin	Only national conservation units, Amazon Basin	Only indirect conservation units, Amazon Basin	Only direct conservation units, Amazon Basin	All protected areas, without institutional covariates, Brazilian Amazon	All protected areas, with institutional covariates, Brazilian Amazon
ATT	-0.0575***	-0.0052***	-0.0601***	-0.0352***	0.0323***	-0.0552***	-0.0499***	-0.0318***	-0.0624***	-0.0538***
SE	[0.0008]	[0.0011]	[.0073]	[.00498]	[.0076]	[.0065]	[.0053]	[.00669]	[.00957]	[0.0065]
N	592,380	592,380	209,628	119,052	89,028	99,414	107,802	203,994	148,914	201,546
Clusters		32,910	11,646	6,614	4,946	5,523	5,989	11,333	8,273	11,197

Conclusions

The findings unveil, besides PAs' effectiveness, the significance of pre-protection effects. These include a "forest rush" two years before conservation units' creation, and a leap in deforestation when the legal process of indigenous land creation begins, followed by a fall in deforestation due to increased state presence, demonstrating the forward-looking behavior of deforesters.

Hence, policymakers should be aware that publicizing information that a site will be protected may increase deforestation in advance, due to forward-looking behavior.

In synthesis, results urge policymakers to plan the creation of PAs not merely seeking to change the tenure of land but mainly to align expectations of deforesters to national conservation goals.

References

1. Callaway, B., & Sant'Anna, P. H. (2021). Difference-in-differences with multiple time periods. Journal of Econometrics, 225(2), 200-230.

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