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The Unequal Impact of Public Mistrust on Labor Markets: Evidence from an Environmental Disaster

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Chilean payments for forest restoration achieved greater environmental impacts when directed toward economically disadvantaged groups

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In a global effort to simultaneously address climate change, biodiversity loss and rural poverty, policymakers are paying landowners to plant and restore forests. However, little evidence exists documenting the impacts that these payments have had and how they can be structured to achieve multiple objectives. Here, we quantify the impacts of Chile's Native Forest Law which paid landowners to restore native forests. The program emphasized equitable development by prioritizing applications from disadvantaged groups. We show that these socioeconomically prioritized projects contributed the greatest increases in forest cover per enrolled hectare. In contrast, larger, wealthier properties who would have been prioritized if program administrators ignored social characteristics provided no additional forest cover. Our results underscore the potential for environmental and development co-benefits from careful targeting of payments for forest restoration.

JEL codes: H0, Q5

Payments for ecosystem services (PES) are often motivated by dual policy objectives: improving environmental conditions and alleviating poverty (1–4). In pursuit of these two objectives, many policymakers target PES towards economically disadvantaged regions or households (5). Such socioeconomic targeting is common across a wide variety of environmental programs, spanning payments for forest conservation in Mexico (6), reforestation in China (7), invasive species control in South Africa (8) and electric vehicle adoption in California (9). When poverty is positively correlated with the environmental impacts of conditional payments, such targeting mechanisms can yield a win-win for the environment and development (10).

Despite this hope, a growing body of literature has raised concerns that socioeconomic targeting of PES may undermine environmental impacts. In the case of payments for avoided deforestation, both systematic reviews (11) and evaluations of individual programs (12–14) have highlighted a troubling tension: payments to higher-income people and places often achieve greater reductions in deforestation. This result can often be explained by the negative correlation between baseline deforestation risk and poverty (15). If poor households are already unlikely to engage in deforestation, paying them to conserve forest is unlikely to generate much behavior change. As such, directing PES to these households creates little additional forest relative to a no-payment counterfactual (16–19). In addition, rural households may face credit constraints that can be relaxed by payments. Thus, paying poor households can help them overcome constraints and engage in deforestation behavior that was previously too costly (20). As a result, PES selection criteria that prioritize poor households often unintentionally weaken a program's environmental performance.

Although there is growing evidence that socioeconomic targeting weakens the environmental performance of payments for avoided deforestation, it is uncertain whether this is true for other PES. Importantly, payments for nature-positive investments such as reforestation or ecological restoration could, in theory, offer greater opportunities for socioeconomic targeting to enhance environmental benefits. In the absence of payments, poor regions that have lower rates of deforestation than rich regions may also exhibit a lower likelihood of active ecological restoration. Similarly, while alleviating credit constraints may allow poor households to accelerate deforestation, it could also enable them to increase investments in resource-intensive restoration activities. Despite these theoretical reasons for why socioeconomic targeting could enhance the environmental impacts of payments for forest restoration, we are unaware of any empirical evidence.

Significance Statement

Prominent initiatives such as the Bonn Challenge, Trillion Trees Initiative, and UN Decade on Ecosystem Restoration hope to address the intertwined challenges of rural poverty, climate change and biodiversity loss through large-scale reforestation and restoration. One way policymakers are pursuing these intertwined goals is to pay poor landowners to restore native forests. Here we measure the impacts of one of the largest of these payment programs, Chile's Native Forest Law. Within this setting, we explore how policymakers' decisions to target payments to economically disadvantaged groups affected the policy's environmental impacts. We find that the law's socioeconomic targeting enhanced its environmental impacts, providing hope for environmental and development "win-wins" from well-targeted payments for forest restoration. We also find suggestive evidence that alleviating liquidity constraints could improve program outcomes, as attrition is common among the disadvantaged landowners that provide the greatest environmental benefits.

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Improved evidence of the environmental impacts of payments for forest restoration is critically important as countries pursue ambitious reforestation targets. Both academics and policymakers have advocated for forest restoration as a near term, large scale and low-cost natural climate solution with valuable co-benefits for biodiversity and rural poverty alleviation (21–23). Initiatives such as the Bonn Challenge, the Trillion Trees Campaign, and the UN Decade on Ecosystem Restoration reflect global efforts to pursue forest restoration as a solution to these intertwined problems (24). As countries begin to scale forest restoration to meet their global commitments, PES is likely to play a major role (25). However, there is limited evidence documenting PES' effectiveness in encouraging forest restoration (26).

Here, we quantify the environmental impacts of Chile's Native Forest Law and explore whether these impacts were enhanced by the law's prioritization of economically disadvantaged applicants. Passed in 2008, the Native Forest Law established an annual subsidy competition to encourage private landowners to restore, manage, or reforest their land using native species. Between 2009 and 2019, more than USD 43 million were allocated through these competitions for projects spanning 235 thousand hectares, making it one of the largest native forest restoration payment programs in the world.

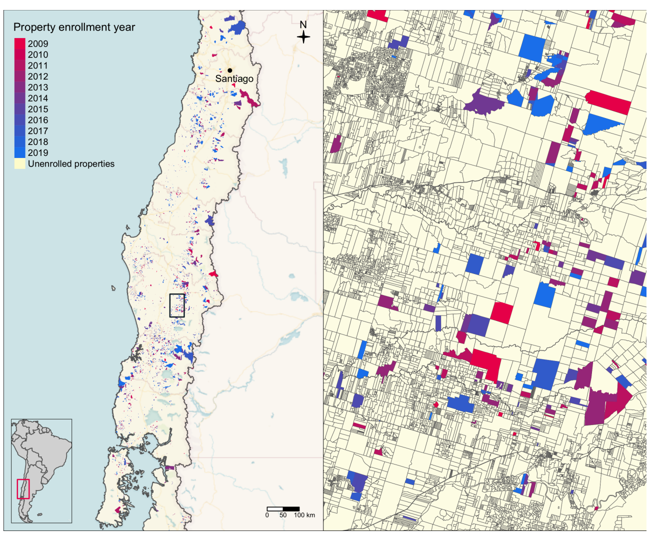

Fig. 1. Properties and their year of enrollment in the Native Forest Law subsidy competition.

The Native Forest Law sought to achieve both environmental and development objectives, stating explicitly that "the spirit of the law is to support rural economic development in balance with environmental protection." To strike this balance in the subsidy competition, Chile's Corporación Nacional Forestal (CONAF) prioritized projects based on applicants' wealth, size of property holdings and affiliation with indigenous communities. In light of this prioritization, the Native Forest Law provides a valuable natural experiment to explore whether targeting for social development enhanced or undermined the environmental effectiveness of payments for forest restoration.

Results

Targeting for social development. Given the Native Forest Law's budget limitations, program administrators targeted payments towards smallholders and other disadvantaged groups through two mechanisms. First, applicants were split into separate smallholder and "other interested party" contests. To qualify for the smallholder contest, landowners had to demonstrate that their total assets and the size of their property fell below a set threshold within each region (full criteria in SI 1). Second, applications in each contest were scored on the basis of both project-specific and social characteristics. Landowners received additional social score points if, for example, they were indigenous or had relatively smaller properties (full scoring details outlined in SI 1). After scoring projects, administrators offered contracts to applicants until their budget was exhausted, moving from the highest to lowest scoring smallholder projects, and then on to the highest scoring projects submitted by other interested parties.

We first examine whether there is evidence that CONAF's strategy to target for social development did indeed help payments go toward landowners in high-poverty areas or with specific social characteristics, as intended. Table S.5 shows how characteristics differ between landowners across the two contests. The program allocated USD 20,175,205 (46.9%) of total funding to the smallholder contest and USD 6,791,707 (15.79%) to landowners residing within indigenous communities or who self-identify as an indigenous race. Although poverty was not explicitly included in the score used to rank applications in the subsidy competition, we find that the social component of the score was positively associated with poverty at the level of applicants' comuna (comparable to a US county) within the smallholder contest. Meanwhile, the project-specific component had no significant association with comuna-level poverty (Table S.3). This relationship holds only within the smallholder contest. Within the other interested party contest, neither the social or project-specific score is associated with comuna-level poverty.

In addition, we explore how alternate scoring systems would affect the prioritization of smallholders and applicants in relatively higher poverty comunas. We consider three counterfactual approaches to ranking the population of submitted projects. Specifically, we reorder projects based on scoring systems in which 1) the smallholder and other interested party contests are combined; 2) social components of the score are eliminated; and 3) neither social scores nor smallholder status were used to prioritize applications. While the actual ranking system used by CONAF heavily favors smallholders, they would have no meaningful advantage in a combined competition (Figure S.9). Further, Figure S.10 illustrates that alternate scoring methods would have deprioritized applicants in relatively higher poverty comunas. This becomes particularly pronounced when the social components of the score are ignored, again suggesting that the social components of the score helped to prioritize applicants from relatively higher poverty comunas.

Low follow-through among selected applicants. More than two-thirds of applicants that were selected to receive Native Forest Law subsidies failed to complete all of the requirements for payment. Much of this attrition was due to landowners' failure to submit an updated native forest management plan within six months of selection – only 37.1% of enrollees did so within the required time frame. Conditional on submitting the management plan, most participants (94.33%) received payment, which required third-party verification of project completion. The conditional nature of the payments helped CONAF avoid paying landowners who did not provide environmental services. However, low follow-through has been a concern for administrators, as it substantially limits the scale of the program.

To explore the drivers of attrition, we quantify the correlation between landowner characteristics and compliance with project conditions (Table S.2). Although selected applicants in the smallholder contest were more likely to follow through than those in the other interested party contest, a higher social score was a significant negative determinant of follow-through for those within the smallholder contest. In other words, smallholders with prioritized social characteristics were less likely than others in the smallholder contest to meet conditions for payment. In the other interested party contest, the social component of the score was not a significant determinant of follow-through. We found that extensionist support, overall subsidy amount, and the project-specific score component were each associated with a significantly increased likelihood of follow-through. In our analyses of land cover impacts in this paper, we focus on the set of properties that did ultimately receive payment.

Payments increased forest extent. Using a combination of matching and difference-in-differences, we evaluate the causal impacts of the Native Forest Law subsidy competition on land use outcomes. In aggregate, we find that the program increased forest extent on the properties of landowners who received payment (Figure 2, panel D; Table S.7, column 1). Our preferred continuous two-way fixed effects (TWFE) specification indicates that enrollment of a landowner's full property led to an average 1.36 percentage point (1.95%) increase in the share of the property covered with forest relative to a "no-payment" scenario. Forest expansion was accompanied by a contraction of cropland and grassland on the properties of participating landowners (Figure 2, panel D; Table S.7, columns 2 and 3). Specifically, property enrollment through the Native Forest Law subsidy competition led to an average 0.97 percentage point decline in grassland (3.85%) and 0.34 percentage point decline in cropland (11.86%).

Event study estimates based on a staggered DID relying on weaker identification assumptions (27, 28) highlight how the effects of payments on land use vary over time (Figure 2). The program led to a more substantial increase in forest for cohorts observed for several years post-enrollment. For the typical enrollee property, which had 20.27% enrolled in the program, the subsidies increased the share with forest by 1.33% 10 years after enrollment. This effect is nearly 5 times more than the aggregate effect across all years, both when using the same staggered DID estimator and when adjusting the continuous TWFE estimate for the average proportion of the property enrolled.

Several falsification tests and robustness checks support the causal interpretation of these findings. First, we consider a falsification test in which we evaluate the outcomes for the subset of properties that were selected through the Native Forest Law competition, but who did not submit a management plan within six months of selection. Because these properties became ineligible to receive payment, it is unlikely that they pursued the planned restoration activities. In this group, we find no statistically or economically meaningful effect of the payments (Table S.7, columns 4-6). Second, our results are robust to several alternative matching specifications (Figure S.6). In addition, we find similar effects using both binary and continuous definitions of treatment and using an estimator robust to general treatment effect heterogeneity (Table 1). When adjusting the continuous TWFE estimate for the average proportion of the property enrolled among those completing the activities (20.27%), the marginal effect of enrollment is 0.002746, nearly identical to the estimate from the staggered DID.

The causal interpretation of our estimates relies on a parallel trends assumption. In our setting, this means assuming that the change in land cover within matched control properties would have been the same as that in Native Forest Law participant properties, had they not participated in the program. While fundamentally untestable (29), the plausibility of the assumption is supported by the fact that pre-treatment trends between the participants and matched

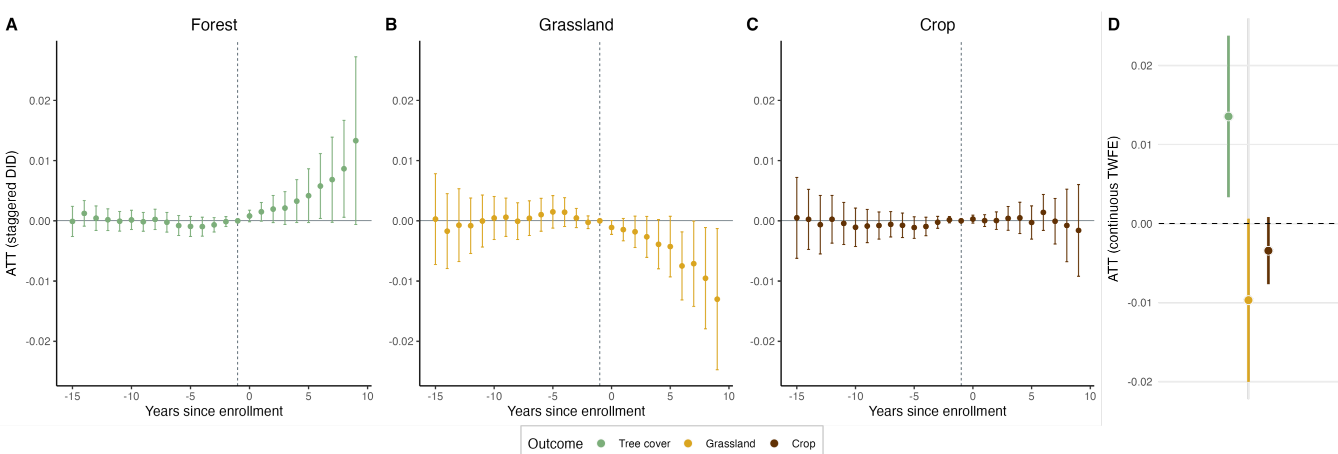

Fig. 2. ATT estimates by event time for A) Forest; B) Grassland; and C) Crop based on the binary staggered DID estimator for all properties that received payments through the Native Forest Law subsidy competition. Panel D shows the aggregate treatment effect estimates for each land cover type based on the continuous TWFE specification.

Table 1. Estimates of the impact of Native Forest Law subsidy payments on forest by estimator

	Continuous TWFE	Staggered DID	TWFE
Treatment intensity	0.013546***		
	(0.00521)		
Binary treatment		0.002751***	0.004098***
		(9e-04)	(0.00149)
Pre-treat mean	0.695	0.695	0.695
N properties	10956	10956	10956

Note:
* p<0.1, ** p<0.05, *** p<0.01; standard errors clustered at property level

control properties were similar up until the point of enrollment for each of the three land cover types we evaluate (Figure 2). In addition, we follow the suggestion of (30) to present event study estimates across land enrollment (treatment dose) quartiles (Figure S.7). This figure illustrates how causal effects evolve over time in different parts of the treatment dose distribution. Importantly, the treatment effects do not appear to be driven by pre-trend violations in a specific dose quartile subgroup. It is also worth noting that higher doses tend to result in higher treatment effects.

Socioeconomic targeting enhanced environmental impacts. To explore how socioeconomic targeting affected the Native Forest Law's environmental impacts, we quantify treatment effect heterogeneity across two dimensions: how treatment effects differ across the smallholder and other interested party contests, and how treatment effects vary across comunas with different levels of poverty (Figure 3). First, we find that the smallholder contest fully drives our finding of positive forest cover impacts (Figure 3 Panel A, Table S.6). In contrast, payments through the other interested party contest yielded no changes in forest cover relative to a no-payment scenario. The disparity in additionality between the two contests is echoed by event-study results in Figure S.4. Smallholders observed for a longer period of time continue to show evidence of increasing treatment effects, whereas no effect arises at any point in time for the other interested party contest. Although enrollees in the other interested party contest did exhibit increases in forest cover, these increases were comparable to increases in forest cover seen in matched untreated properties (Figure S.5). This indicates that the larger, wealthier landowners in the other interested party contest would likely have increased forest area even without payments, representing a lack of additionality.

Second, we find that projects in high-poverty comunas achieved greater environmental impacts than projects in comunas with lower poverty rates (Figure 3 Panel B). Figure S.8 highlights that both the smallholder and other interested party contests exhibited a positive relationship between comuna-level poverty and payments' forest cover impacts. Although program administrators did not use any explicit measure of poverty to target payments, their social score was highly correlated with comuna-level poverty in the smallholder contest (Table S.3). In tandem, these results are suggestive that the social component of CONAF's scoring system helped prioritize directing payments towards high-poverty comunas which, in turn, yielded greater environmental impacts.

Finally, we consider how our counterfactual methods of ranking the population of submitted projects affect the environmental impacts of the subsidy contest. Using the estimates of treatment effect heterogeneity, we predict the individual treatment effect for each project. We find that

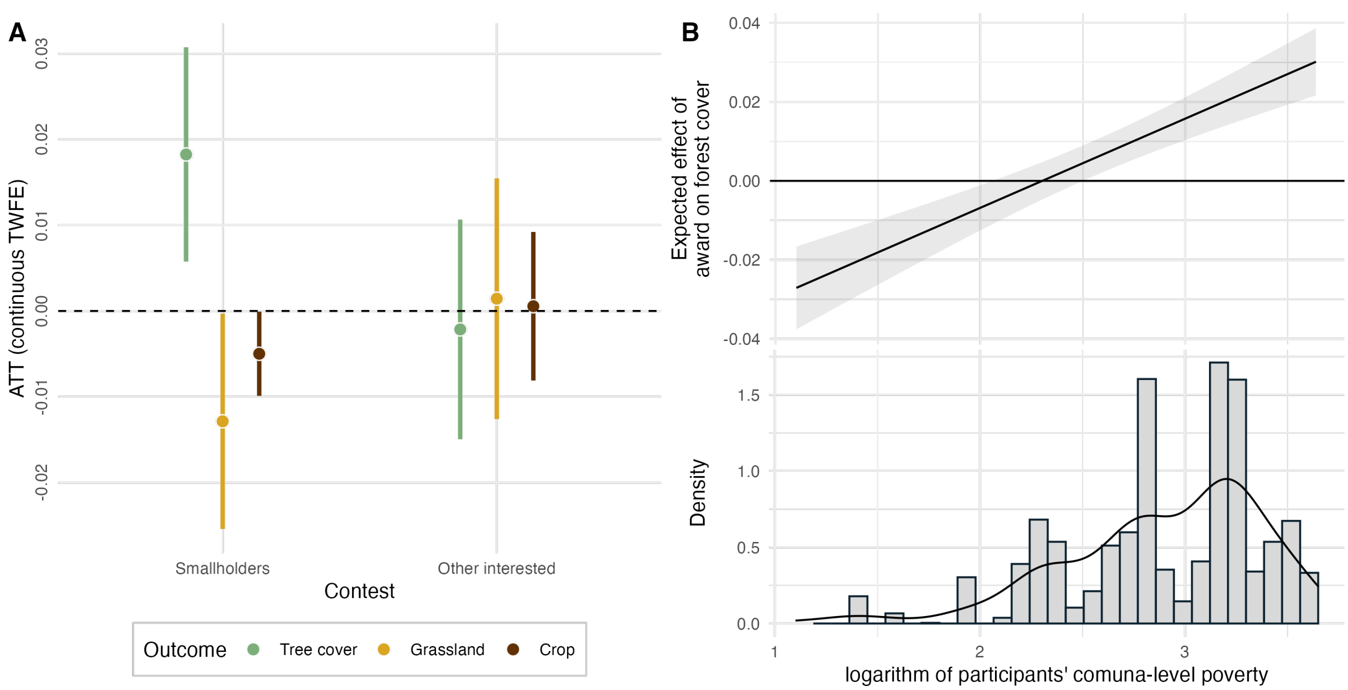

Fig. 3. Social targeting improved environmental outcomes. A) Estimated treatment effects of the Native Forest Law subsidy contest for beneficiary properties across the Smallholder and Other Interested Party contests. B) Marginal effects plot shows that increased comuna-level poverty is associated with increased treatment effects. The distribution of comuna-level poverty among selected applicants is shown at bottom.

ending the Native Forest Law's preferential treatment of smallholders would lead administrators to prioritize projects with much lower expected treatment effects (Figure S.11). If the contests were to remain separate, ignoring social scores would not lead to substantial declines in the expected environmental impacts. However, a counterfactual program design with neither of these socioeconomic targeting mechanisms would rank the best-performing projects at the bottom of the priority distribution and the lowest-performing projects at the top. When funding is constrained, socioeconomic targeting can lead to substantial variation in the overall additionality of the program. Figure 4 illustrates that separating smallholders from the other interested parties leads to greater overall program impact than either combined contest scenario, regardless of the percentage of requested funding that is awarded. Combining contests and ignoring social characteristics leads to the lowest program impact when less than 77% of requested funding is awarded. Importantly, we find that under the existing ranking system, program impacts would be maximized when only 60% of requested funding is awarded. In the first years of the competition, funding was not constrained. Although the program has gained popularity, CONAF was still able to award 79% of the total requested funding in the 2024 competition. This means that administrators could achieve greater increases in forest cover with a smaller budget.

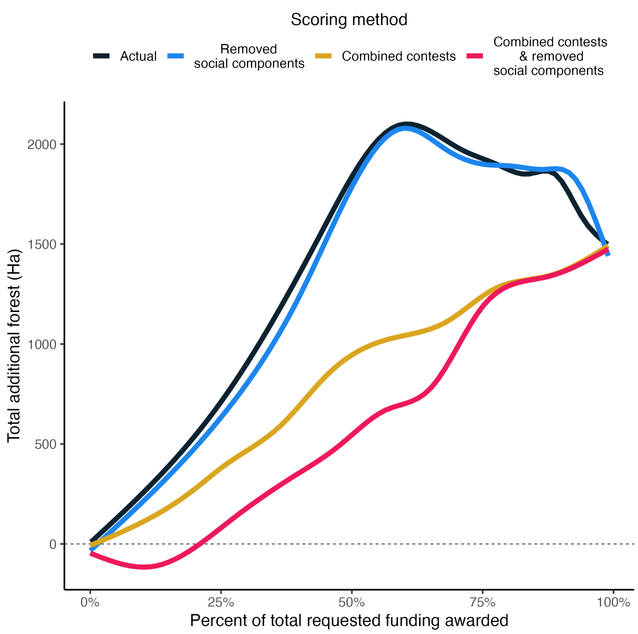

Fig. 4. Cumulative additionality (Total additional hectares of forest) according to alternate scoring approaches and percent of requested funding allocated.

Discussion

Impacts of payments for forest restoration. Our results indicate that the Native Forest Law subsidy contest increased the extent of forests on recipient landowners' properties relative to a no-payment counterfactual. In line with many other PES evaluations (20, 26), our estimated effects are modest in magnitude. Enrollment of one hectare in the Native Forest Law's payment program is expected to yield 0.0136 hectares of additional forest cover in our main specification, suggesting relatively low additionality. Other observational impact evaluations of reforestation payments that yield plausibly causal results suggest similar concerns, particularly for native forests. For example, forestry incentives in Guatemala led to overall increases in forest cover of less than 10% of enrolled area (31). Similarly, PES incentivizing forest restoration in Brazil's Atlantic Forest (32, 33) and China's Grain for Green program (34) led to minimal forest cover impacts. Findings of substantial additionality are limited largely to afforestation in silvopastoral systems (35, 36), although there is some evidence for large effect sizes in the context of plantation forests. A notable example is Chile's Decree Law 701, which subsidized monoculture plantations of exotic eucalyptus and pine. Recent impact evaluations of the law have yielded mixed findings of relatively high (37) and low (38) additionality. In addition, the subsidies led to the conversion of native forests into monoculture plantation (38).

Despite relatively low additionality, back of the envelope calculations indicate that the average smallholder was paid USD 91.58 per tonne CO_2 stored in aboveground biomass (see S.1). Although greater than Chile's current official social cost of carbon (USD 64.30), it is below both recent estimates of the true social cost of carbon (39) and the carbon price that would allow Chile to achieve net zero emissions by 2050 (40).

Potential for environment and development win-wins from well targeted forest restoration payments. Policymakers often adopt policies in pursuit of multiple objectives, but achieving them simultaneously with a single instrument can prove difficult (41). In the context of PES, administrators' targeting strategy will undermine environmental benefits if prioritized characteristics are positively correlated with their likelihood of providing environmental services even in the absence of payments (10). This has often been the case with payments for avoided deforestation, in which prioritization of poor landowners generally reduces environmental effectiveness (42). To our knowledge, no study has addressed whether socioeconomic targeting enhances or undermines the environmental effectiveness of payments for forest restoration. In this article, we provide evidence that lends hope for win-wins in this context.

Why do our findings contrast with the results of prior analyses of payments for avoided deforestation? Credit constraints may offer one key explanation. Poor rural households often face credit constraints that prevent them from engaging in large-scale deforestation (43, 44). As a result, areas of high poverty often face relatively low deforestation pressure. In addition, payments to poor landowners can help households overcome credit constraints, potentially increasing deforestation within unenrolled landholdings (12, 20, 45). However, credit constraints may also prevent poor households from making costly, long-term investments in restoration or reforestation. In this context, payments that help overcome credit constraints can allow landowners to engage in environmentally beneficial activities that were previously prohibitively costly. Credit constraints, while a major obstacle to win-wins in the avoided deforestation setting (20), may thus provide a compelling justification to target forest restoration payments to the poor.

In addition to the theoretical explanations above, we find empirical evidence suggesting that in the Native Forest Law competition, such credit constraints explain at least some of the greater additionality among smallholders in high-poverty areas relative to better resourced landowners. First, in the absence of payments, smallholders engage in less reforestation than larger, wealthier properties. Before participating in the program, landowners in the smallholder contest had less forest on their properties than those in the other interested party contest. Further, landowners in the other interested party contest were increasing the share of their property with forest at a much quicker rate than smallholders even prior to engaging with the Native Forest Law subsidies (Figure S.5). Second, among selected smallholders, follow-through is lowest among those with prioritized social characteristics. This same pattern did not emerge in the other interested party contest, perhaps indicating that among landowners with sufficiently high assets and large land holdings, constraints did not differ substantially. Although smallholders did exhibit higher rates of follow-through broadly, this was in part because they benefited from features of the program such as more extension support and higher payments. In combination, these findings suggest that the most disadvantaged landowners may face credit or liquidity constraints that prevent them from making the initial investments necessary to complete contracted activities.

Increasing impacts in forest restoration payments. While our study highlights the potential for effective socioeconomic targeting in payments for forest restoration, we identify several ways in which policymakers could improve program impacts. In particular, alleviating credit constraints among marginalized applicants could help the program succeed. First, this could reduce low follow-through. Above, we illustrated that low follow-through rates emerge in the Native Forest Law competition, likely because some landowners struggle to make up-front investments. CONAF avoided costly unconditional payments by requiring verification of activity completion. However, credit and liquidity constraints likely contribute to landowners' inability to make initial investments, and the conditional nature of the payments itself may reduce follow-through (46).

Second, increasing both follow-through and broader participation of priority groups through greater outreach and access to extension services could increase the overall impacts of the program. Because payments to smallholders and landowners in high-poverty areas yielded the most additional forest cover gains, increasing follow-through rates of these groups specifically could increase the expected environmental benefits per enrollee. Although not causal, we found that selected smallholder applicants with extensionist support were 13 percentage points more likely to follow-through (Table S.2), highlighting the potential effectiveness of such support. In addition, paying larger, wealthier landowners to restore forests yielded no additional forest. This suggests that simply increasing the representation of applicants from groups that were likely to be additional could increase the expected forest cover gains from payments. Given that, under the existing ranking system, the overall additionality of the program would be maximized when awarding the first 60% of the total requested funding, reallocating the budget away from nonadditional enrollees and toward extension services and outreach could increase overall program impacts.

Limitations. Although we believe our analysis provides useful insights into the design of payments for forest restoration, we note several limitations that leave gaps for future research. First, although we identify heterogeneity in the causal effects of the Native Forest Law subsidies based on margins of social prioritization, we do not causally identify the precise cause of this heterogeneity. We are able to isolate patterns of impact across poverty within comunas, but poverty is unlikely to directly cause increased impacts. This does not affect our claim that CONAF's decision to send payments to high-poverty comunas increased environmental benefits, but we are unable to explain when we would expect to see similar outcomes in other settings. One contributing factor to the distinction in impacts seen between the smallholder and other interested party contest may be the difference in the scale of payments across the two contests. The composition of the participants may be affected by the slightly higher payments in the smallholder contest for the same set of activities. Had the other interested party contest been eligible for higher payments, more additional landowners could have selected into the program. Although we provide suggestive evidence that credit constraints could be one possible mechanism driving heterogeneity, future work should further explore the factors that underpin heterogeneous impacts in payments for forest restoration contexts.

Second, while we show that the pursuit of social objectives enhanced the environmental goals of the Native Forest Law, we cannot show that payments to poor landowners actually reduced poverty. In PES, there exist underlying tradeoffs between poverty alleviation and behavior change. Specifically, the fact that prioritized landowners did change their behavior to provide additional forest cover means that the action was costly, and it is unclear to what degree payments exceeded opportunity costs, a necessary condition for recipients to be strictly better off (4). Future work should focus on the degree to which this targeting actually improved livelihoods among the poor.

Lastly, our relatively small estimated effect size can be explained, in part, by the fact that landowners can receive subsidies for restoration and management activities in already standing forest, so not every subsidized hectare is expected to add new forest area. In addition, our estimated effects are substantially greater when looking several years beyond initial enrollment (Figures 2 and S.4). Even 10 years after program enrollment, dynamic effects do not appear to have leveled. One possible explanation for this is that our remotely sensed measure of forest extent is unable to differentiate young forests from shrublands. As a result, there may be a significant delay between investments made by landowners to plant forests, and our ability to detect those forests. This would mean that our later event-time estimates provide more accurate estimates of the aggregate impact that payments achieve. As such, we emphasize the importance of tracking long-term land cover impacts for evaluating payments for forest restoration.

Conclusion

With forest restoration emerging as a leading natural climate solution, our study of Chile's Native Forest Law yields several policy-relevant takeaways. First, payments for forest restoration do influence land use, increasing forest extent on recipient properties. Although not all forest restoration is additional, we find that payments generate relatively cost-effective carbon removal (USD 91.58 per tonne CO_2 when directed to smallholders).

Second, socioeconomic targeting of payments can increase the expected impact of payments. In the Native Forest Law competition, smallholders and poorer applicants exhibit greater additionality than their wealthier counterparts with larger land holdings. Although prior efforts to target payments for avoided deforestation to the poor have often undermined their environmental benefits, targeting these landowners in payments for forest restoration can simultaneously increase transfers to the poor while increasing environmental benefits.

Finally, although credit constraints and limited technical capacity may help explain why targeting payments to poor households improves the effectiveness of payments for forest restoration, both limit the ability of poor households to comply with payment conditions. Complementary policies such as those that provide poor landowners with credit needed to make costly up-front investments or extension services that bolster landowners' technical capacity could increase their participation and the environmental impacts of the policy.

Materials and Methods

Data. We obtained property boundaries for all rural properties in the major forested regions of Chile as of the year 2009. Data on the awarded properties are available through CONAF and reflect aspects of the property and projects such as project objective, project surface area, subsidy amount, whether a management plan was submitted within six months, and whether the payment has been made. Also included is each property's parcel identifier, which is unique to each property within a comuna, Chile's level 3 administrative unit. We match the enrolled properties to their corresponding boundaries via this unique parcel identifier.

In order to quantify environmental impacts of the Native Forest Law, we use annual measures of land cover. Our primary outcomes of interest come from annual Landsat (30m) resolution maps of land cover developed in (47). These maps classify pixels into one of the following classes for each year between 2000 and 2018: forest, crop, grassland, shrub, and bareground. While many studies use satellite derived measures of deforestation to generate annual panels of forest loss, very few studies leverage annual variation in specific land cover types outside of those focused on North America, Europe, and the Amazon. Further, the product was developed specifically to produce more consistent estimates of land cover change over long time periods and gradual change events such as restoration.

Second, Landsat resolution land-use classification maps of these regions in Chile developed in (38) allow us to distinguish the proportion of each property engaged in specific land uses prior to the existence of the Native Forest Law. Of particular interest is the distinction between plantation forest and native forest. In contrast to native forest, high levels of plantation forest may indicate greater ability to manage forest and undertake contracted activities. All of our satellite derived measures cover the extent of the major forested areas of Chile, representing the regions that contain the vast majority of Native Forest Law enrollees.

Application scoring and poverty. While we cannot observe individual landowner poverty, we examine whether poverty at the level of landowners' comuna is associated with social and project scores:

$$ln(ComunaPov_i) = \rho_0 + \rho_1 ln(social_i) + \rho_2 ln(project_i) + X_i + e_i \quad [1]$$

, where $ComunaPov_i$ represents poverty (in %) within the Comuna where landowner i resides. Here, a 1% increase in the social score for landowner i, $social_i$, is associated with a ρ_1 increase in comuna-level poverty, holding $project_i$ constant. Similarly, a 1% increase in the project-specific score for landowner i, $project_i$, is associated with a ρ_2 increase in comuna-level poverty, holding $social_i$ constant.

Determinants of Follow-through. Although CONAF avoided unconditional cash transfers by verifying project completion, the association of priority characteristics with follow-through informs our understanding of the effectiveness of the program's design. In order to examine how prioritization of social characteristics in the Native Forest Law scoring system was correlated with follow-though, we use regressions of the following form:

$$completed_i = \psi_0 + \psi_1 ln(social_i) + \psi_2 ln(project_i) + X_i + u_i \quad [2]$$

, where $completed_i$ is a dummy variable equal to 1 if landowner i followed through and received payment for successful project completion.

Pre-processing methods. To quantify the environmental impacts of the Native Forest Law subsidy contest, we focus on landowners who complied with program requirements and received payment. A key concern with evaluations of programs with voluntary participation is that apparent effectiveness may actually be due to different participation costs (10). Landowners choose to enroll in the program and, in theory, would only participate if their opportunity cost is equal to or lower than the program payment. This means that the average enrollee likely has lower participation costs than the average unenrolled landowner. Simply using unenrolled properties as the counterfactual would be ill-advised, since unobservable factors affecting enrollment could drive changes in forest cover outcomes, not the program itself.

To move toward a more convincing counterfactual, we first use matching as a pre-processing technique to generate a control group from among all unenrolled rural properties in the major forested regions of Chile. This should yield control properties with more similar opportunity costs to enrollees than among the general population. This approach is similar to many recent studies evaluating PES (14, 48) and other forest conservation policies (49, 50).

The covariates used for matching include environmental and economic characteristics likely to determine enrollment decisions and project performance. We include pre-enrollment property land-use including native forest, plantation forest, and pasture, derived in (38). Landowners with similar land allocation within a property should face a similar decision about whether to enroll in a program involving native forest management. Other included covariates give a sense of a property's productive potential, remoteness, and market access. We also match on pre-treatment trends of the outcome, which should make estimated effects more credible by increasing confidence in the common trends assumption (51). Matches are made with replacement based on nearest neighbor propensity scores from a logit model. Our main approach includes the three unenrolled nearest neighbors for each program enrollee in the control group. Our main results do not change when using an alternative number of nearest neighbors or when restricting paired matches to 0.25, 0.5, 1 and 2 caliper of standard deviation differences in their covariate values (Figure S.6).

Table S.4 displays balance checks for all covariates used and demonstrates that prior to pre-processing, enrolled and unenrolled properties differ significantly. The normalized mean difference and variance were reduced for nearly every covariate after the matching process. Figure S.3 shows that comparability between selected covariate distributions drastically improved between treatment and control properties after matching.

Difference-in-differences method. We take advantage of our panel data setting and estimate the following equation to reveal the land cover impacts of the Native Forest Law subsidy contest:

$$outcome_{it} = \beta_0 + \beta_1 intensity_{it} + \gamma_i + \lambda_t + \epsilon_{it} \quad [3]$$

, where $outcome_{it}$ represents the share of property i engaged in a specific land cover outcome in year t; $intensity_{it}$ represents the proportion of property i enrolled through the Native Forest Law subsidy contest in year t; and γ_i and λ_t represent property and year fixed effects, respectively. Property fixed effects (γ_i) control for unobserved time invariant characteristics such as landowner preferences. Year fixed effects (λ_t) control for time-varying shocks that are common across all properties such as changes in other environmental policies. Our coefficient of interest, β_1, recovers the impact of enrollment in the Native Forest Law contest, conditional on follow-through.

Equation 3 falls under the umbrella of two-way fixed effects (TWFE) estimators. This literature has received ample attention in recent years, particularly in the case of binary treatment (i.e., whether a property enrolled) (52–54). In this context, binary treatment would ignore the proportion of the property enrolled through the contest. Equation 1 is valuable in our context, because the average landowner that ultimately receives payment enrolls 20.27% of their land in the program, with significant variation across properties.

Importantly, $intensity_{it}$ represents a continuous treatment in the context of TWFE estimation. (28) decompose TWFE estimators when treatment is continuous and show that β_1 represents the weighted average change in outcomes from incremental changes in land enrollment across and within periods. Thus, our identification relies on the following assumption: properties that enrolled an additional increment of land in the Native Forest Law contest, must experience the same evolution in outcomes as properties that never enrolled the increment. The event study approach relaxes this assumption at the cost of ignoring a property's treatment intensity.

The dynamics of payments for ecosystem services are important, and perhaps moreso in the restoration context. Forest is not established instantaneously, including in satellite-derived measures of forest, where a pixel is generally only classified as forest if it exceeds a threshold of canopy cover. Survivorship of trees is also key, as many planting initiatives have led to minimal long-term success (55). These factors are echoed in the Native Forest Law payment scheme, where landowners are not even eligible to receive their payment in the first year of enrollment.

We use the staggered DID estimator developed in (27) to generate event study treatment effects, where the year prior to enrollment is used as the universal baseline to avoid confusion on interpretation of pre-treatment estimates (56). It is important to note that this estimator relies on binary treatment. While this cannot account for the fact that properties enroll only a selected proportion of a property, it provides robustness properties not true of Equation 3. First, our event study estimates rely on a relatively weaker conditional common trends assumption. Common trends need only hold after conditioning on our detailed set of time-invariant pre-treatment characteristics. The estimator is also robust to general treatment effect heterogeneity (57) and does not suffer from concerns about interpretability with continuous treatment (28).

Heterogeneous impacts of payments. To answer the question of whether the Native Forest Law's strategy to target for social development undermined environmental impacts, we consider several variables that correspond to application prioritization and socioeconomic status. We examine how environmental effectiveness differed across the smallholder and other interested party contests. We both estimate Equation 3 and compute event study estimates for landowners who follow through from each contest separately.

In order to understand how the effectiveness of payments varied across finer-grain measures of vulnerability, we explore heterogeneity based on comuna-level poverty. Although poverty was not explicitly used by program administrators to target funding, higher values of $social_i$ are associated with higher comuna-level poverty (Table S.3), and poverty alleviation is generally the primary goal of targeting payments to marginalized groups.

$$\begin{aligned} forest_{it} =& \alpha_0 + \alpha_1 intensity_{it} + \alpha_2 intensity_{it} \times ln(ComunaPov_i) \\ &+ \gamma_i + \lambda_t + e_{it} \end{aligned} \quad [4]$$

Here, α_2 is the parameter of interest, which yields the association of $ComunaPov_i$ with the treatment effect of the Native Forest Law subsidies on forest.

Importantly, α_2 does not reveal the effect of poverty on subsidy effectiveness, but instead, indicates whether payments that were targeted toward higher poverty comunas were more effective than those toward relatively lower poverty comunas.

Counterfactual impacts under alternate scoring systems. To calculate the counterfactual environmental impacts under alternative scoring scenarios, we fit the point estimates from the following specification to individual applicants to generate individual treatment effects:

$$\begin{aligned} forest_{it} =& \alpha_0 + \alpha_1 intensity_{it} + \alpha_2 intensity_{it} \times ln(ComunaPov_i) \\ &+ \alpha_3 intensity_{it} \times ln(ComunaPov_i) \times Smallholder_i \\ &+ \gamma_i + \lambda_t + e_{it} \end{aligned} \quad [5]$$

We then calculate the rank of each applicant according to each counterfactual scoring approach to understand how applicants' rank under each system correlates with their expected environmental impacts.

Data, Materials, and Software Availability. The data and code needed to replicate these results will be made available on Github.

ACKNOWLEDGMENTS. We are grateful for useful feedback received by Kelsey Jack, Andrew Plantinga, Kathy Baylis and other members of the UCSB Environmental Economics group. We also thank seminar participants at the University of Minnesota, University of Rhode Island, Stanford University, Oregon State University, Environmental Defense Fund, and University of Utah for helpful comments. Funding for this work was provided by the Arnhold Family Foundation.

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Supporting Information for

Chilean payments for forest restoration achieved greater environmental impacts when directed toward economically disadvantaged groups

Albert Garcia and Robert Heilmayr

This PDF file includes:

Supporting text
Figs. S1 to S7
Tables S1 to S8

Supporting text

Additional background on Chile's Native Forest Law. Chile's long history of public policies supporting tree cover expansion provides an incredibly useful setting in which to measure the impacts of payments for restoration. Chile's decree law no. 701 (DL 701) is one of the world's longest operating afforestation subsidies, but mainly promoted even-aged mococulture plantations of eucalyptus and pine that had negative effects on biodiversity and native forest extent (38).

In an attempt to encourage the recovery and protection of native forests, Chile sought to pass the Ley de Recuperación del Bosque Nativo y Fomento Forestal (Native Forest Law) as a successor to DL701 (58). Initially expected in 1994, it became frozen in legislature before finally passing in 2008. In addition to new protections for native forests, the law created an annual competition for grants to support new projects that restore existing native forests or plant new ones.

The subsidy component of the law encourages three types of activities: 1) the regeneration, restoration or protection of native forests for conservation; 2) silvicultural activities aimed at restoring native forests for timber production purposes; and 3) silvicultural activities aimed at restoring native forests for non-timber production purposes. Of the 12,889 projects enrolled between 2009 and 2019, 10,912 (84.66%) restored native forest for the purposes of timber production. Examples of subsidized activities include thinning, enrichment planting (introduction of trees to degraded forest), and establishment of new forest via tree planting. Few estimates of the impacts of the Native Forest Law on land cover currently exist. CONAF estimated the carbon impacts of the Native Forest Law through 2019 as it relates to Chile's Nationally Determined Contribution (NDC) as part of the Paris Agreement (59). However, these estimates assume that the carbon stored by every eligible subsidized hectare is the direct result of the law. Such an approach ignores the concept of additionality, since some of this forest would likely exist even in the absence of the law.

Details for the competition's scoring. The program used a scoring system in order to assign project funding priority within each contest. Projects were granted funding in descending order of score until the allocated funding had been assigned. This meant that projects sometimes went unfunded because of a low score, although no ex-ante cutoff existed. This was particularly common in the other interested party contest, which was granted funding after the smallholders. In some years, a second smallholder contest was held, causing smallholders to go unfunded because of low scores. The scoring criteria include factors related both to landowner, property, and project characteristics. This score, although not always critical for smallholder applicants, provides insight to program administrators' preferences for project prioritization. Specifically, CONAF scores the applicants according to the following formulas:

$$score_{smallholder} = \psi_s \times VT + \lambda_s \times VP + \gamma_s \times VI + \beta_s \times VPS \qquad [6]$$

and

$$score_{otherinterested} = \psi_o \times VT + \lambda_o \times VP + \gamma_o \times VI \qquad [7]$$

, where

- VT = Land/forest characteristics; this considers the type of forest, the forest's state of development, and the project's contribution to the conservation of the country's biological diversity via the specific species used.
- VP = project characteristics; this considers the subsidy amount, including whether the applicant will finance part of the bonus amount per hectare. It also considers whether the project is complimentary to existing Native Forest Law projects, the state of the management plan, and burned forests.
- VI = landowner and property characteristics of interest; this considers property size (higher scores to smaller properties) and whether the applicant belongs to an indigenous community.
- VPS = additional characteristics of social priority; this considers whether the project is of social value to specific communities of interest (i.e., indigenous communities)
- γ, β, λ, and ψ represent the weights given to each category in the respective contests

For the purposes of our counterfactual scoring exercise, we split the score into two components, $social_i$ and $project_i$. These represent our interpretation of score components deemed to be of social importance and components of the score representing project specific characteristics unrelated to the landowner themselves or the size of the full property:

$$social_i = \gamma VI + \beta VPS$$

$$project_i = \lambda VP + \psi VT$$

Smallholder contest eligibility. A smallholder must generally meet all of the following requirements:

- A person who has title to one or more rural properties whose surface area does not exceed 200 hectares, or 500 hectares when they are located between regions I and IV , including the XV; or 800 hectares for properties located in the comuna of Lonquimay, in Region IX; in the province of Palena, in the X Region; or in Region XI and XII
- Their assets do not exceed the equivalent of 3,500 unidades de fomento
- Their income comes mainly from agricultural or forestry exploitation and they directly work the land, on their property or on another third-party property

The following also qualify as smallholders:

- Agricultural communities regulated by decree with force of law No. 5, of the Ministry of Agriculture, of 1968
- Indigenous communities governed by Law No. 19,253
- Communities over common property resulting from the Agrarian Reform process
- Societies dry land constituted in accordance with Article 1 of Decree Law No. 2,247 of 1978
- The companies referred to in Article 6 of Law No. 19,118, provided that at least 60% of the capital stock of such companies are in the hands of the original partners or persons who have the status of small forest owners, as certified by the Agricultural and Livestock Service

Event-study estimates. Recent papers have shown that the typical two-way fixed effects estimator may generate biased results in the presence of treatment effect heterogeneity (e.g. 54, 57). This could be particularly important in our case, given that there are over 150 cohort-time cells. The estimator developed in (27) computes each 2x2 cohort-time treatment effect ($ATT_{g,t}$) individually, before aggregating them with weights proportional to cohort size.

The estimand for each of the $ATT_{g,t}$s is as follows:

$$ATT_{g,t} = E[outcome_{it}(1) - outcome_{it}(0)|G_i = g, t \geq t_o]$$

Each $ATT_{g,t}$ then represents the treatment effect for cohort g in time t. To generate the $ATT_{g,t}$s, we first subset the data to only contain observations at time t and $g-1$, from units with either $G_i = g$ or that are in the control group. For example, for the $ATT_{2015,2019}$, we subset to only the 2015 cohort and control group for the years 2014 and 2019. Then using only the observations from this subset, we calculate $ATT_{g,t}$ using the doubly robust difference-in-differences estimator developed in (60). This involves first estimating a propensity score using a logit model and allows for common trends to hold only after conditioning on pre-treatment covariates. With this method, we can identify the $ATT_{g,t}$s if either (but not necessarily both) the propensity score or outcome regression is correctly specified (60).

We focus on event study measures of the ATT. Within each event time window, we aggregate the $ATT_{g,t}$s with weights corresponding to group size.

$$ATT_{es}(e) = \sum_{g \in G} \mathbb{1}\{g + e \leq \mathcal{T}\} P(G_i = g | G_i + e \leq \mathcal{T}) ATT_{g,g+e}$$

This is the average effect of participating in the treatment e time periods after a characteristic property is enrolled in the program across all cohorts that are ever observed to have participated in the treatment for exactly e time periods. The year a property enrolls in the program is denoted by $e = 0$.

Carbon price calculation. Our estimates of the carbon price are based on our estimated impacts of the Native Forest Law competition's land cover impacts in addition to existing estimates of carbon per hectare for native forest cover, crop, and grasslands by region in Chile. While this estimate relies on assumptions about the carbon content of additional forest, we believe it to be relatively conservative. Estimates of carbon content per hectare of native forest used in this calculation are based on mature native forests by region in Chile. This means that this estimate assumes all additional forest extent is mature native forest. While this number may overestimate the current carbon content in newly established native forest subsidized through the Native Forest Law, we believe it is reasonable to assume subsidized forest will eventually mature and attain these levels of carbon content. Moderating factors include the fact that our estimates are unable to capture carbon benefits achieved through restoration of already standing forest, which is relatively common among subsidized projects. Second, as seen in our event study estimates (Figures S.4; 2), forest impacts are increasing through time. Estimates from Equation 3 do not account for these dynamics and may further underestimate the ultimate carbon impacts of the program if recent cohorts see dynamic effects similar to the earliest cohorts. These factors lend confidence that our primary estimate is not a significant underestimate of the true final cost.

Supplementary tables and figures

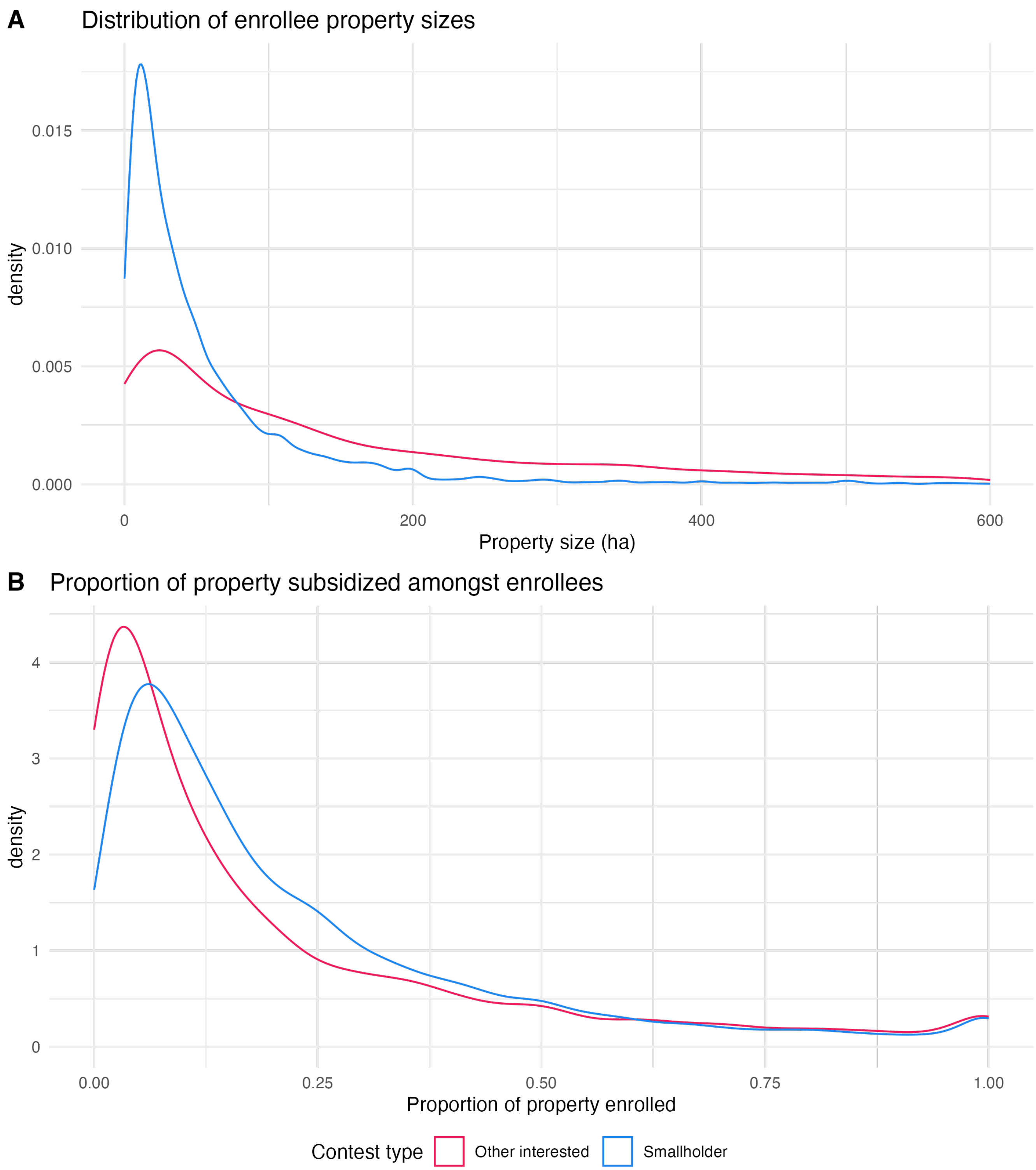

Fig. S.1. Distribution of A) property size; and B) proportion of property enrolled among enrollees in both contests; and B)

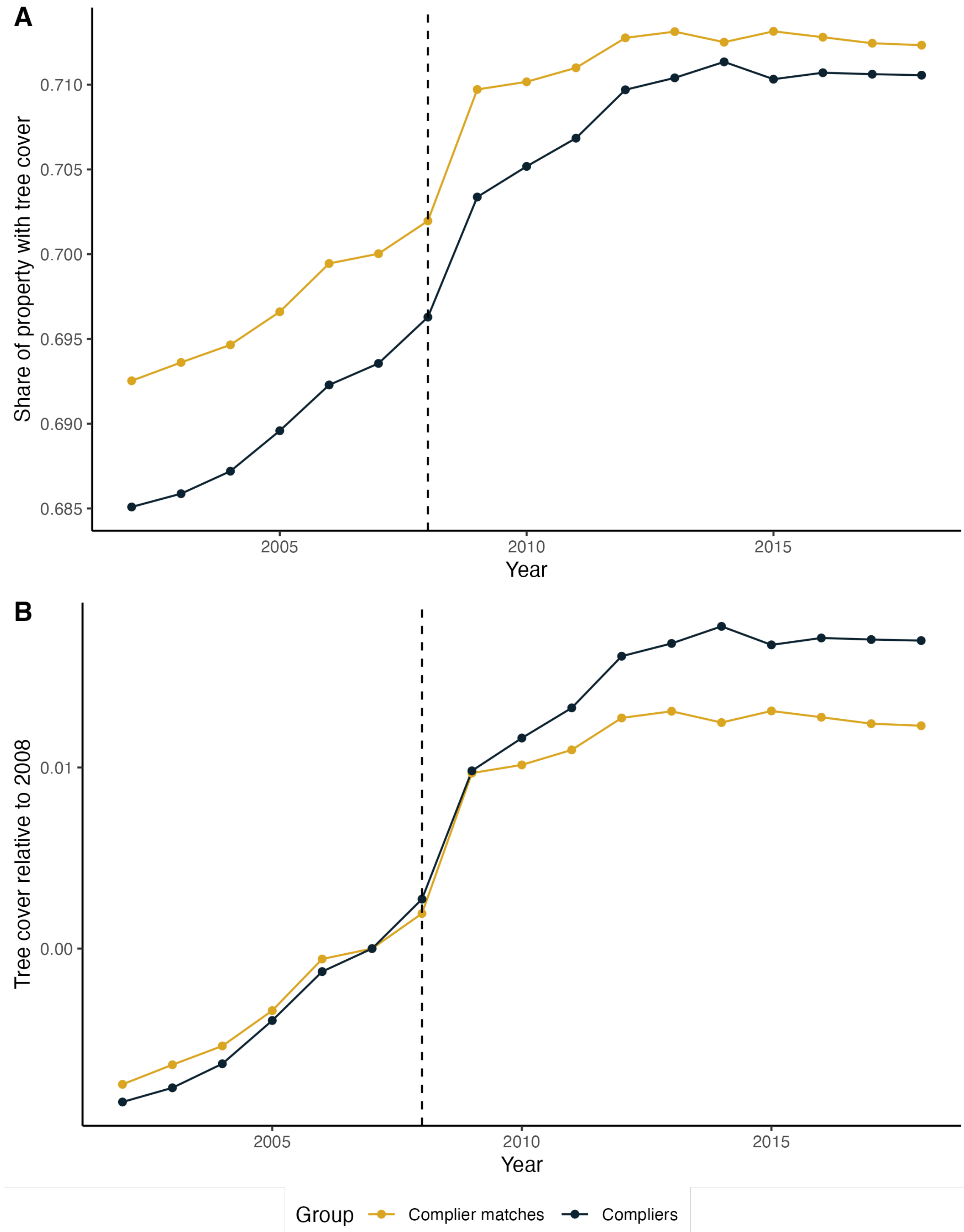

Fig. S.2. A) Raw trends in forest share between enrolled properties and matched control properties; and B) de-meaned forest trends relative to 2007, the year prior to the Native Forest Law passing.

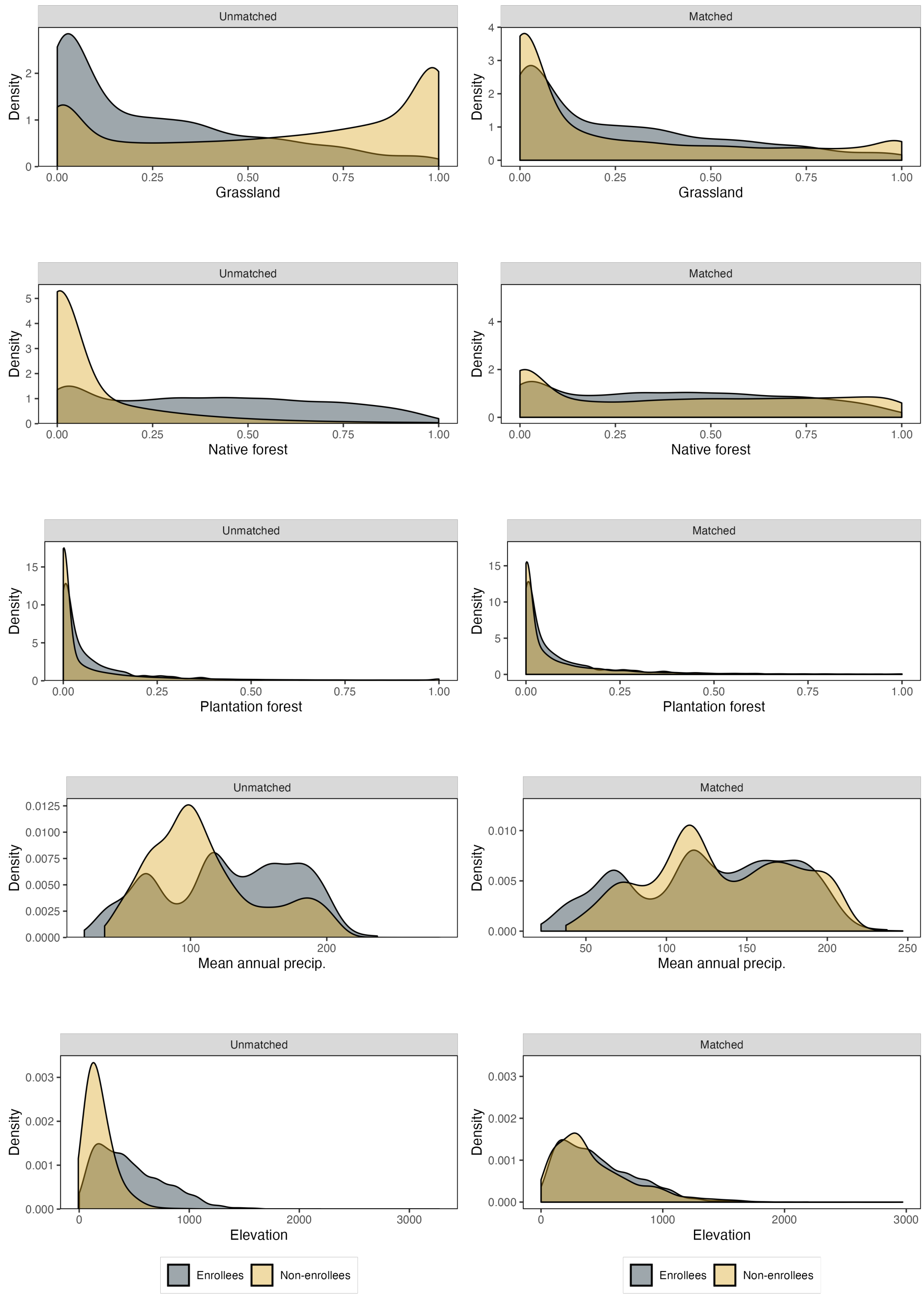

Fig. S.3. Distribution balance for selected covariates before and after matching. The left panel shows distributions of covariates for treated and unenrolled properties. The right panel shows the same for treated and matched control properties.

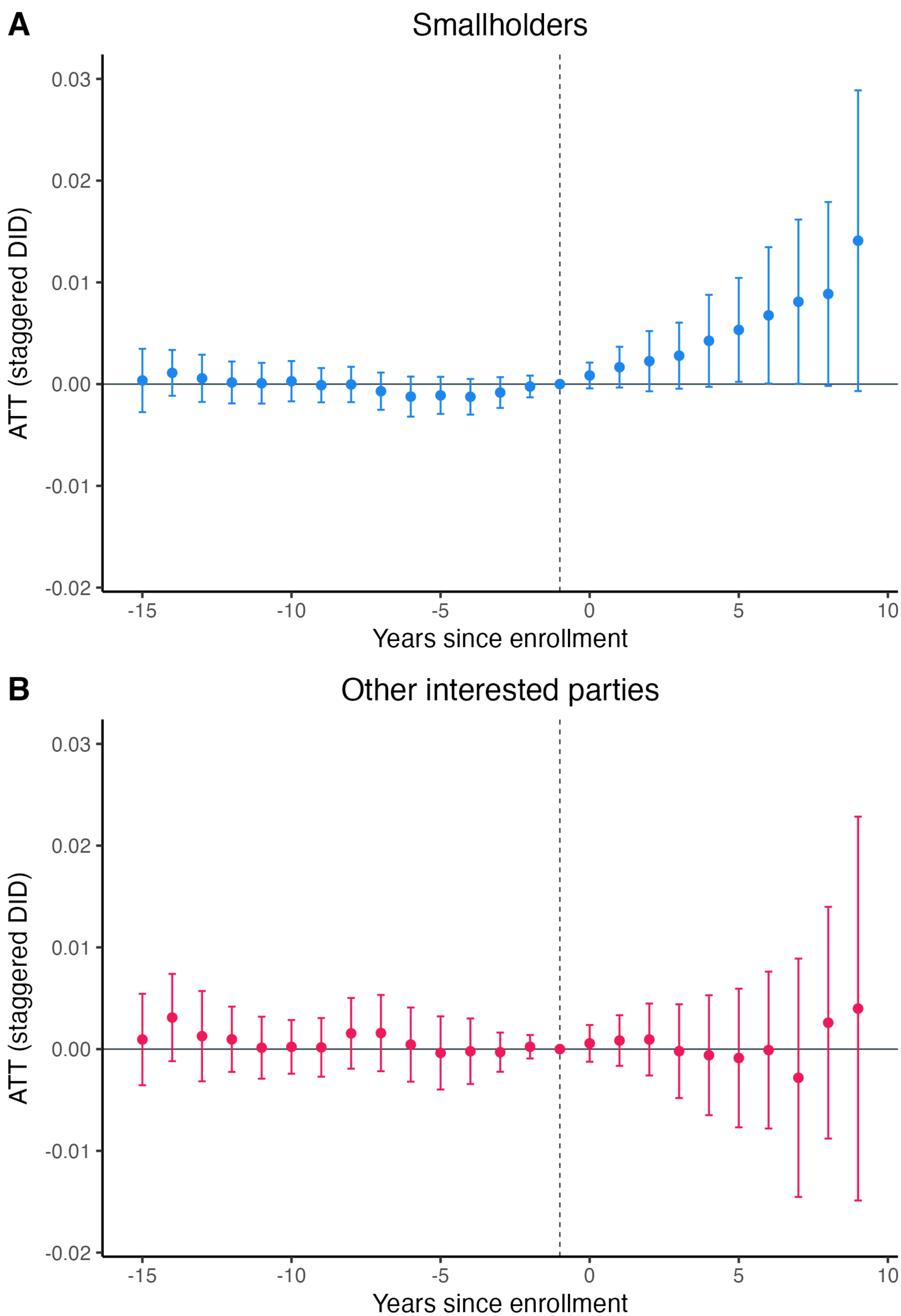

Fig. S.4. Event-time forest cover impacts of the Native Forest Law subsidy contest for beneficiary properties in the A) Smallholder contest; and B) Other Interested Parties contest

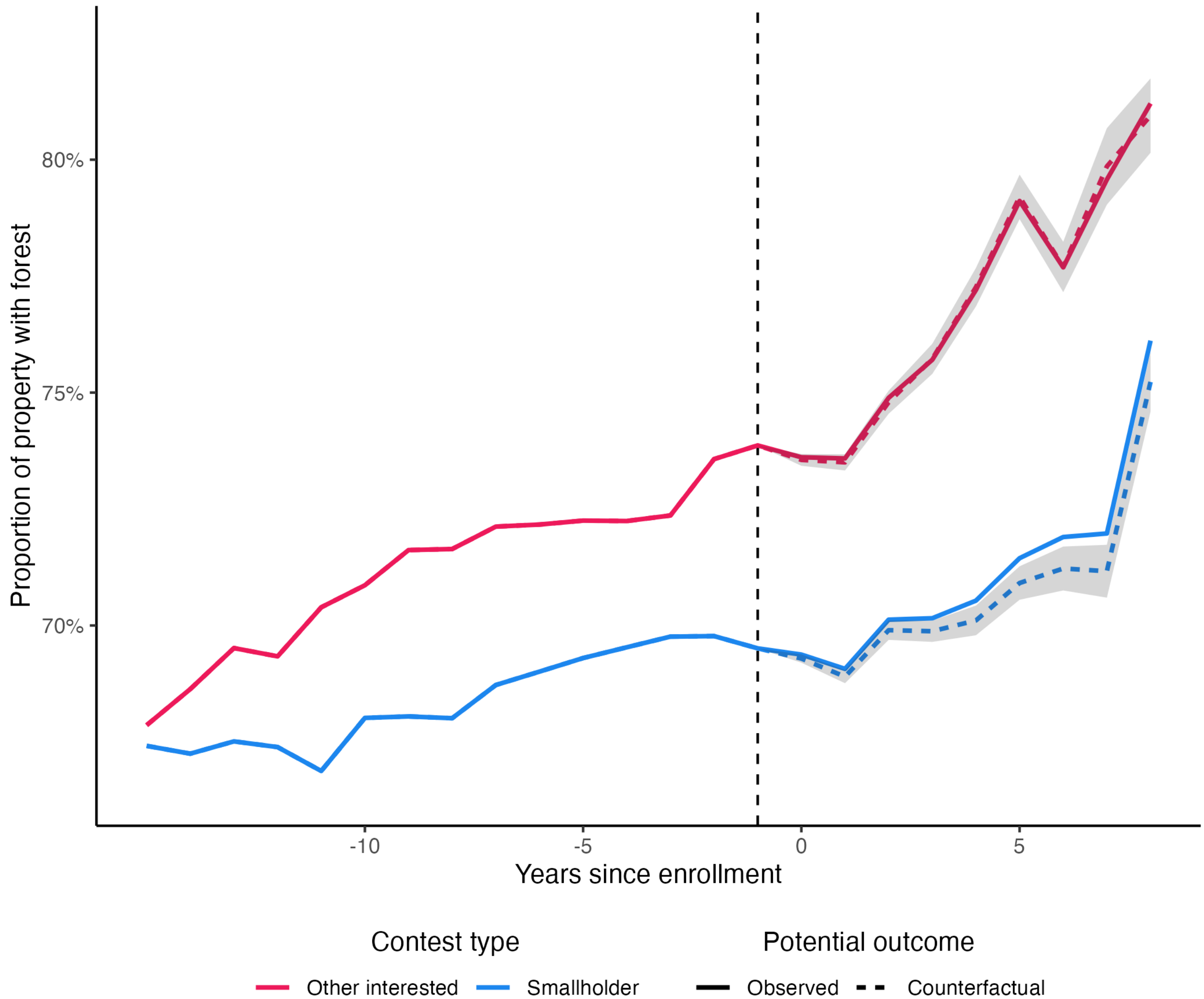

Fig. S.5. Potential outcomes by event-time within the Smallholder and Other Interested Party contests. Estimates of the counterfactual are based on the staggered DID event study estimates. Shaded areas represent the 95% confidence intervals.

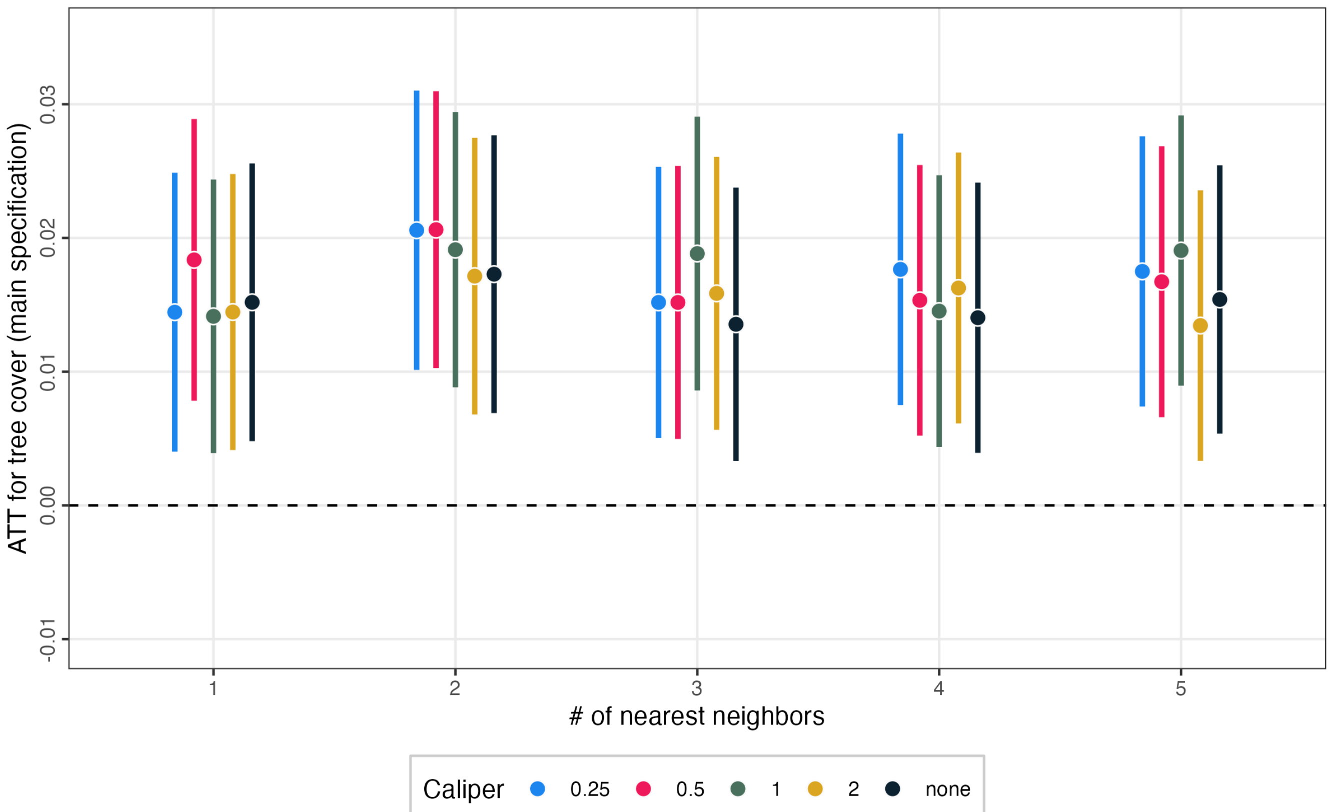

Fig. S.6. Alternate decisions for matching procedure yield comparable results. The estimated ATT for forest is plotted based on different ratios of nearest neighbors (1:N) and restrictions on the caliper of standard deviation differences in paired matches' covariate values

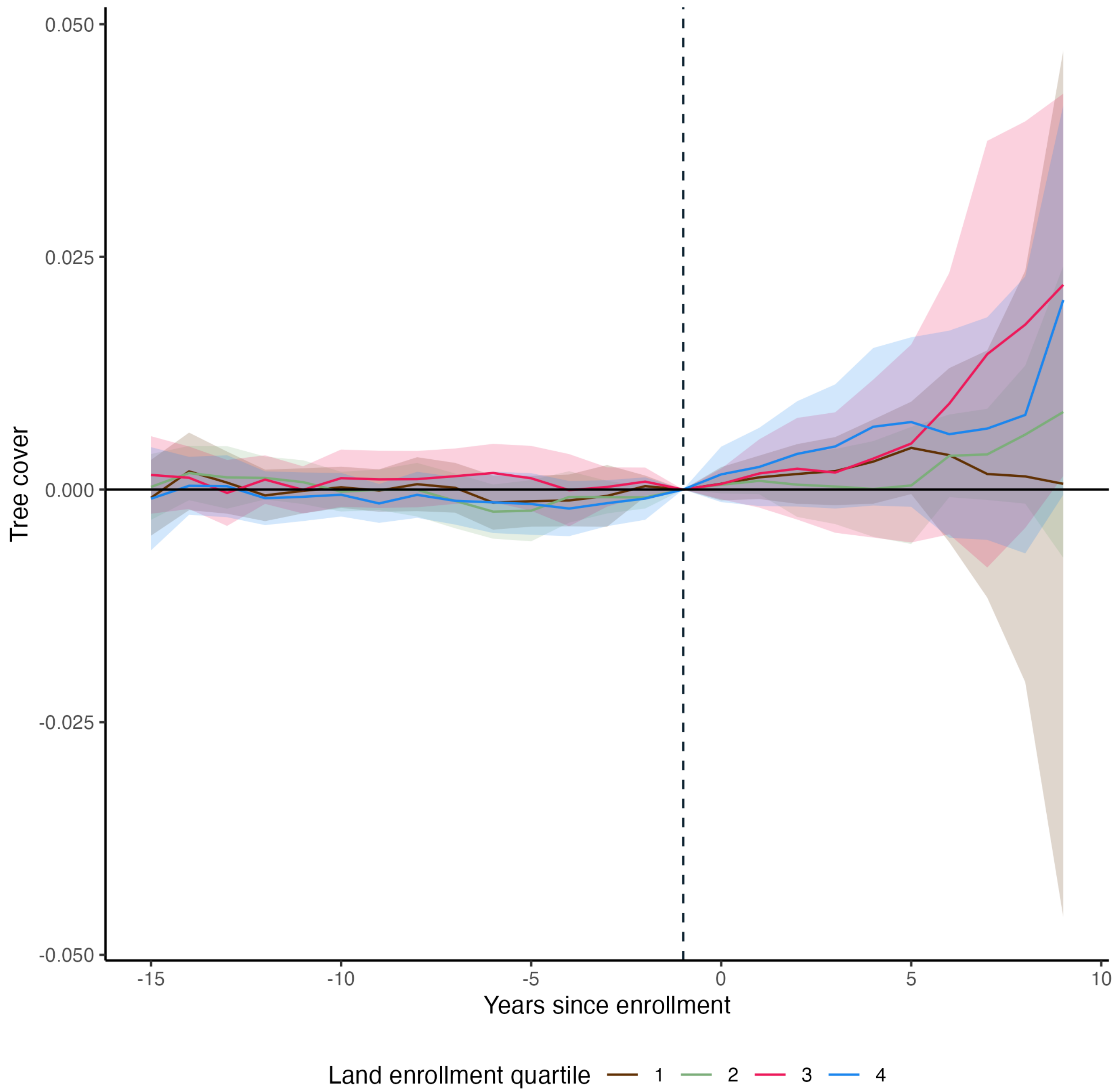

Fig. S.7. Event-time forest cover impacts of the Native Forest Law subsidy contest for beneficiary properties by quartile of land enrolled.

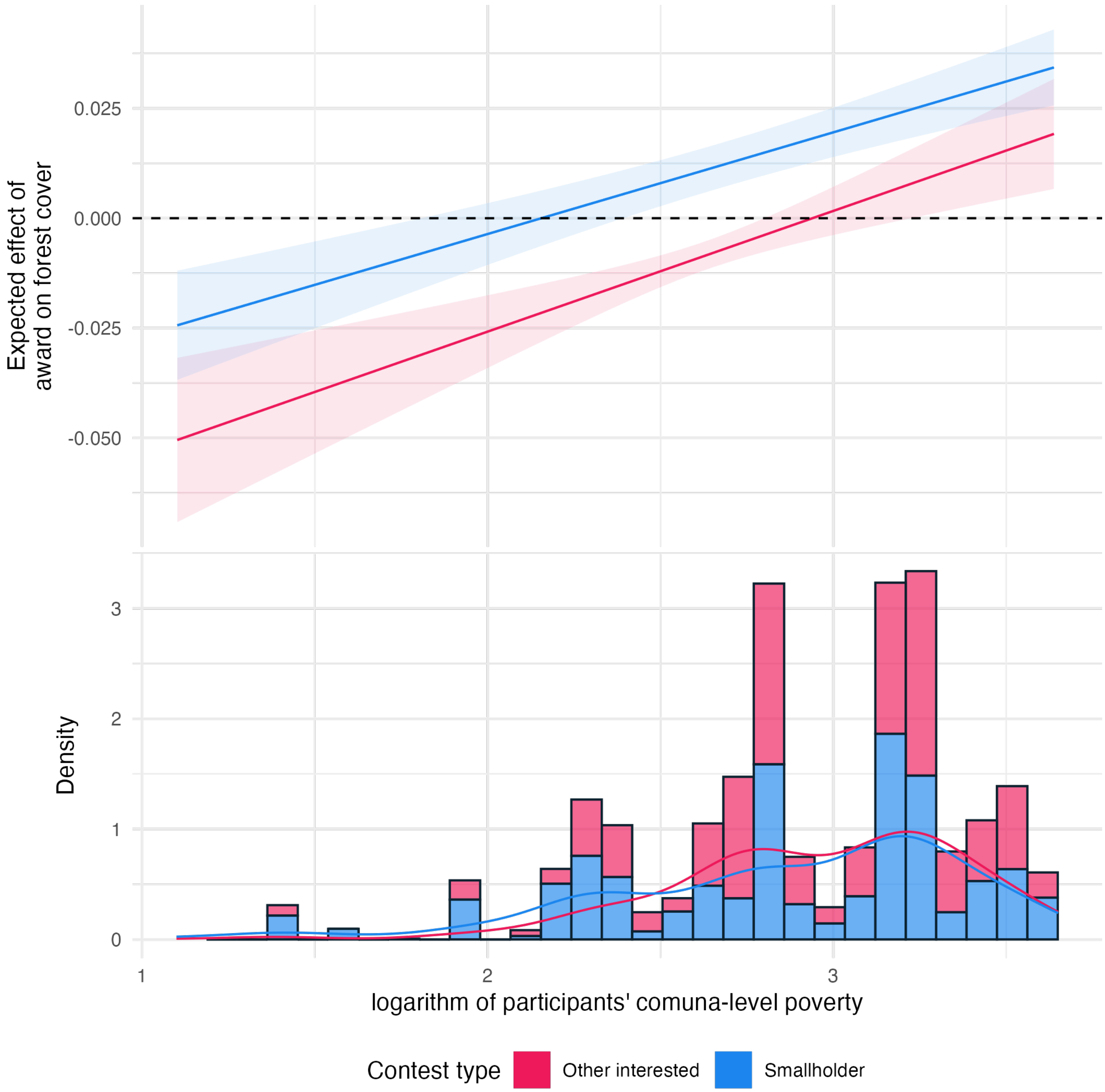

Fig. S.8. Marginal effects plot shows that increased comuna-level poverty is associated with increased treatment effects across both the smallholder and other interested party contests. The distribution of comuna-level poverty among selected applicants by contest is shown at bottom.

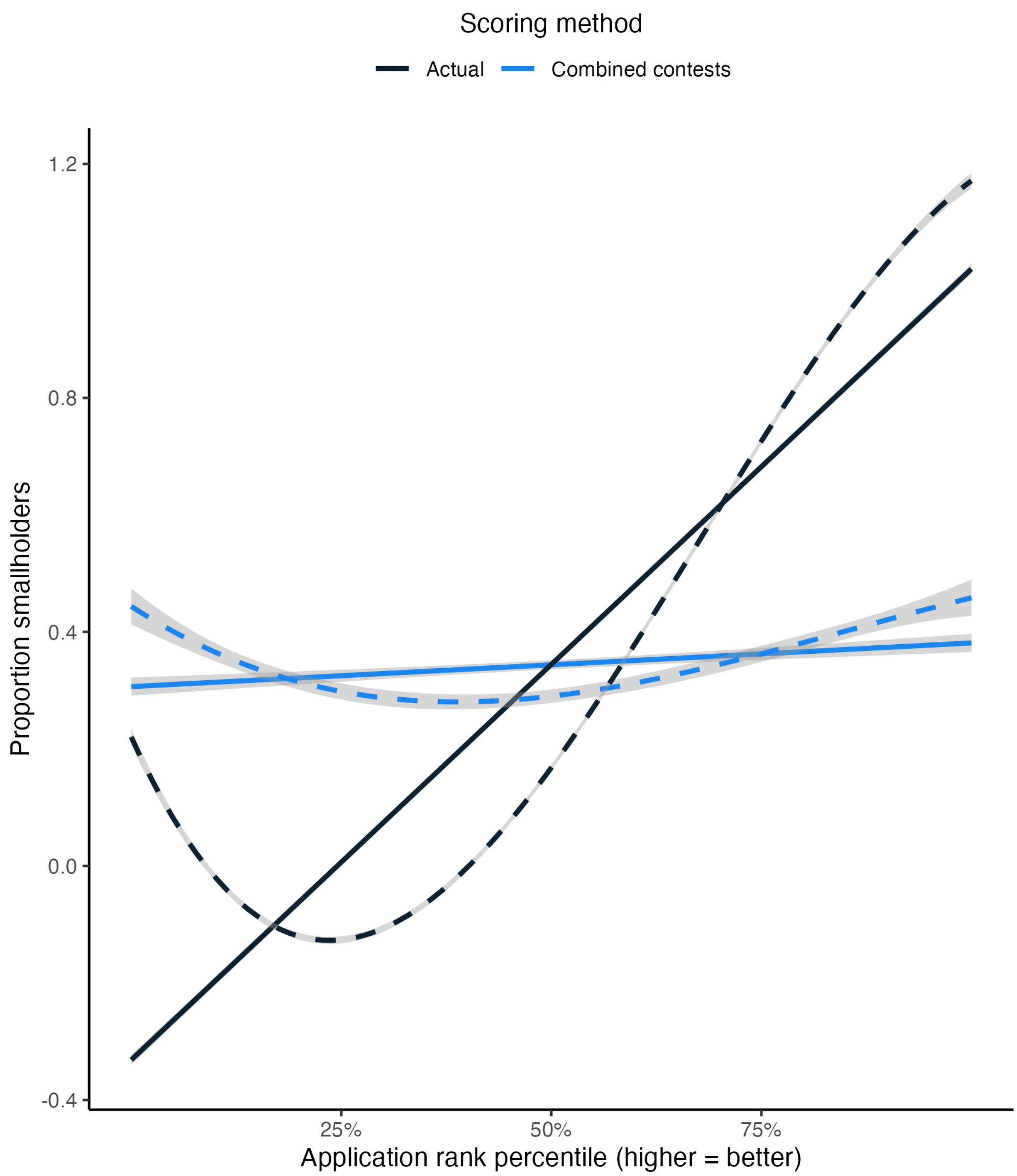

Fig. S.9. The proportion of applicants classified as smallholders against application rank under alternative scoring systems. Solid lines show fitted linear regression lines. Dashed lines show cubic splines.

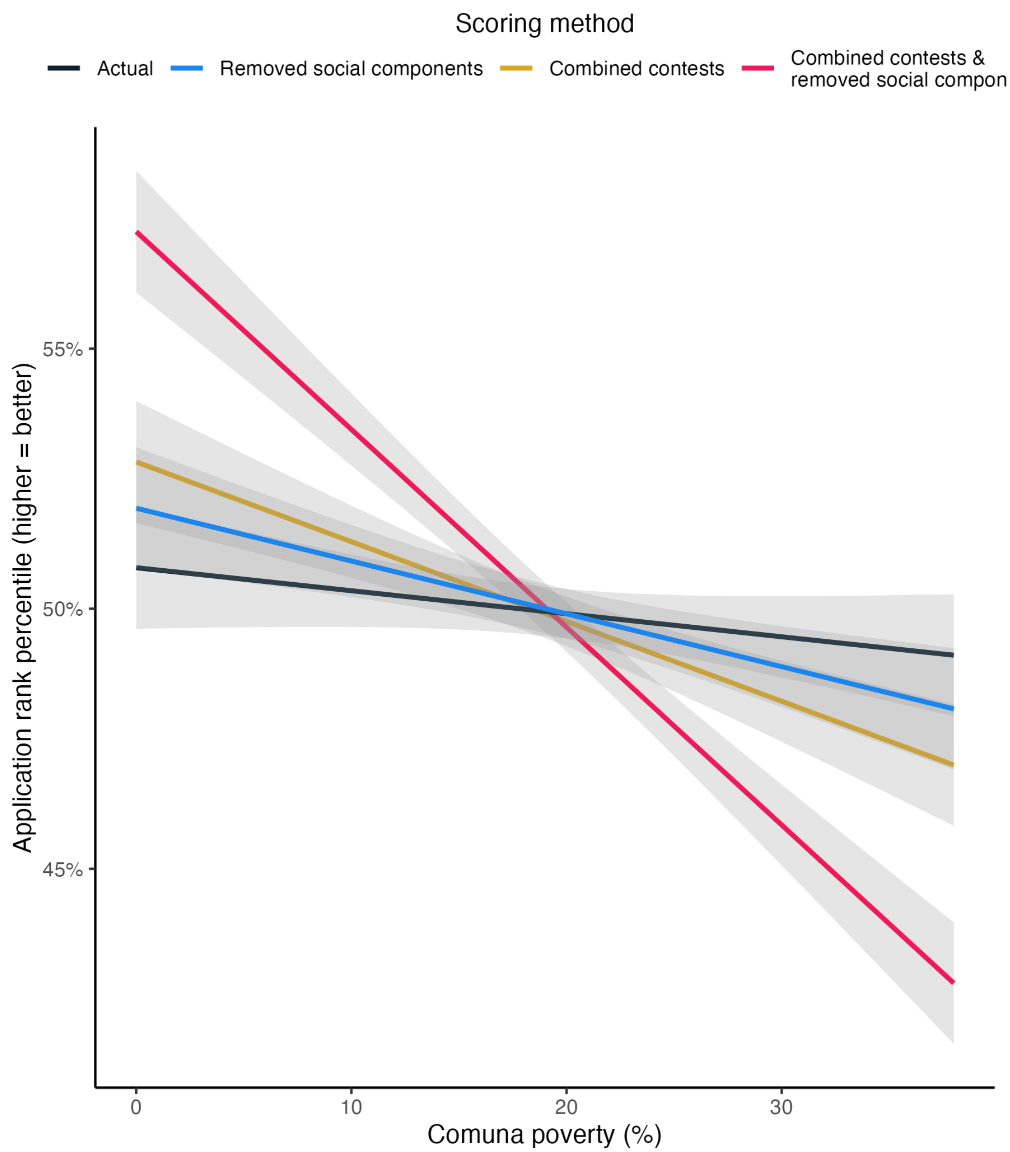

Fig. S.10. The relationship between applicants' comuna level poverty and their ranking under alternate scoring systems. Compared to the actual scoring system, alternate approaches all lead to a more downward sloping relationship between priority and comuna poverty.

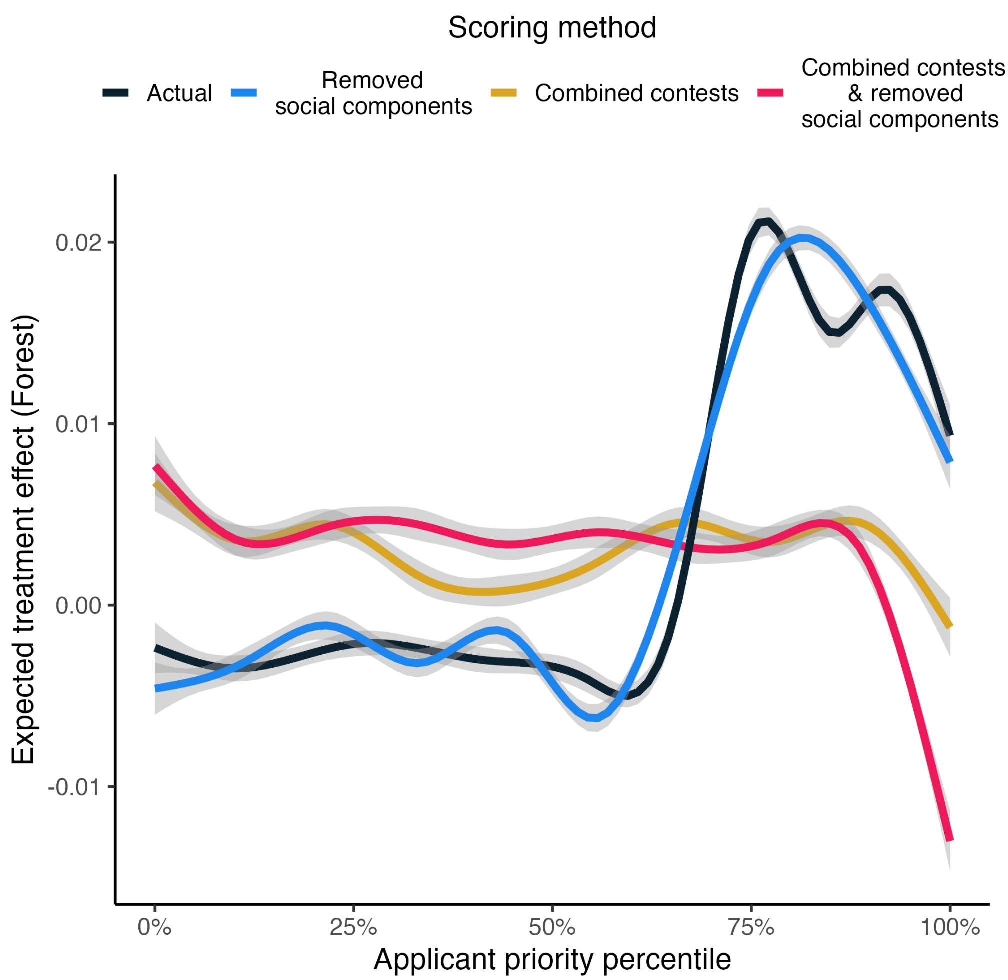

Fig. S.11. Conditional means of the expected environmental impacts by applicant rank according to alternate scoring approaches. Shaded areas represent 95% confidence intervals.

Table S.1. Summary statistics describing participants in the Native Forest Law subsidy competition

Variable	Mean	Median	Std. dev.
Application characteristics			
Property size (ha)	447.99	46.90	2383.75
Subsidized area (ha)	19.13	5.93	153.36
Bonus amount (USD)	3239.24	1205.94	8482.16
Percent of property subsidized	22.43	13.65	23.69
Comuna poverty (%)	19.03	18.00	8.44
Timber production objective (%)	84.64	100.00	36.05
Received extensionist support (%)	44.99	0.00	49.75
Follow-through			
Submitted management plan (%)	37.11	0.00	48.31
Received payment (%)	35.04	0.00	47.71
Property accessibility			
Dist. to sawmill (km)	10.82	9.22	7.98
Dist. to native timber processing (km)	21.34	15.34	17.34
Dist. to city (km)	40.01	33.49	34.41
Elevation (m)	434.16	361.75	320.12
Land cover			
Native forest (2001 %)	40.26	40.29	28.66
Plantation (2001 %)	8.25	2.63	13.09
Tree cover change (pp, 00-08)	1.58	0.09	5.26
Crop (2008 %)	2.38	0.00	9.83
Grassland (2008 %)	24.67	14.76	26.09
Shrubs (2008 %)	1.95	0.00	7.77

Table S.2. Social score is negatively associated with compliance for smallholders.

Outcome var.	Complied			
	(1)	(2)	(3)	(4)
ln(Social score)	-0.07997***	0.00597	0.05292	0.01135
	(0.02024)	(0.03622)	(0.03573)	(0.03614)
ln(Project score)	0.06305***	0.06491***	0.07373***	0.08401***
	(0.01340)	(0.01346)	(0.01332)	(0.01342)
ln(ComunaPov)	0.00146	0.00345	0.01230	0.01235
	(0.01295)	(0.01297)	(0.01292)	(0.01288)
Smallholder	0.11573***	0.41503***	0.55489***	0.49911***
	(0.01023)	(0.10594)	(0.10477)	(0.10507)
ln(Social score) x Smallholder		-0.12038***	-0.18226***	-0.15359***
		(0.04229)	(0.04186)	(0.04204)
Extensionist			0.13050***	0.13178***
			(0.00842)	(0.00842)
ln(Subsidy amount)				0.02427***
				(0.00348)
Num.Obs.	12828	12828	12828	12821
R2	0.075	0.076	0.093	0.096
AIC	16468.3	16462.7	16222.8	16172.6
Subsample	Full sample	Full sample	Full sample	Full sample
Region FE	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Standard errors are clustered at the property level.

Table S.3. Social score is associated with relatively higher comuna level poverty for smallholders.

Outcome var.	ln(ComunaPov)			
	(1)	(2)	(3)	(4)
ln(Social score)	0.07363***	0.08282***	0.19447***	-0.00574
	(0.01293)	(0.01330)	(0.01678)	(0.02952)
ln(Project score)	-0.01432	-0.01590*	-0.00181	0.02199
	(0.00907)	(0.00909)	(0.01102)	(0.01715)
Timber production objective		0.00133	-0.01523	0.02021
		(0.00831)	(0.01000)	(0.01462)
ln(Subsidy amount)		-0.00594**	0.00538	-0.00520
		(0.00257)	(0.00338)	(0.00421)
Num.Obs.	12828	12821	8744	4077
R2	0.617	0.617	0.646	0.590
Subsample	Full sample	Full sample	Smallholders	Other interested parties
Region FE	Yes	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Standard errors are clustered at the property level.

Table S.4. Covariate balance before and after matching.

	Norm. mean difference		Variance	
Variable	Unmatched	Matched	Unmatched	Matched
Native forest	-1.30288	0.05048	0.37094	1.38986
Plantation forest	0.07752	0.01679	2.28871	1.50483
Tree cover	-1.01878	0.02740	1.32224	1.31412
Grassland	0.97514	-0.01664	1.87329	1.50167
Crop	0.04902	-0.01695	1.41754	1.40925
Shrubs	-0.00220	-0.02344	1.61923	1.50870
Developed	0.22859	-0.00774	616.59818	1.14370
Water	0.05219	0.08484	151.33645	122.23824
Property area (Ha)	-0.27850	-0.12724	0.01879	0.97613
Elevation	-1.13221	-0.06360	0.20818	1.16261
Latitude	-0.16815	-0.03118	0.82963	0.93248
Population	0.45343	-0.00876	16.53557	1.01131
Mean annual precip.	-0.37145	0.13746	0.69875	0.80644
Dist. to sawmill	-0.58908	-0.06275	0.53809	1.65084
Dist. to native industry	-0.08321	-0.03773	0.96840	1.04149
Dist. to nearest city	-0.43939	0.07452	0.85817	1.04888

Table S.5. Comparison of Native Forest Law competition participants in the Smallholder versus Other Interested Parties Contests.

Variable	Contest mean		T-test p-value
	Smallholders	Other interested	
Award (USD)	2230.54	5375.44	< 0.001
Subsidized area (ha)	12.25	33.68	< 0.001
Property area (ha)	133.56	1114.38	< 0.001
Timber production objective (%)	85.46	82.89	< 0.001
Elevation (m)	408.76	487.39	< 0.001
Native forest (%)	39.60	41.63	0.008
Plantation (%)	7.12	10.62	< 0.001
Grassland (%)	26.73	20.37	< 0.001
Crop (%)	2.09	2.99	0.001
Shrub (%)	1.67	2.56	< 0.001
Dist. to native timber processing (km)	20.48	23.13	< 0.001
Dist. to sawmill (km)	10.42	11.66	< 0.001
Dist. to city (km)	41.59	36.68	< 0.001

Table S.6. Estimates of subsidy impact across Smallholder and Other Interested Parties contests

	Smallholders			Other Interested Parties		
Outcome	Tree cover	Crop	Grassland	Tree cover	Crop	Grassland
	(1)	(2)	(3)	(4)	(5)	(6)
Intensity	0.01824**	-0.00499*	-0.01286*	-0.00215	0.00055	0.00143
	(0.00637)	(0.0025)	(0.0064)	(0.00653)	(0.00442)	(0.00716)
Num.Obs.	136098	136098	136098	60984	60984	60984
R2	0.975	0.923	0.962	0.971	0.916	0.957
Control group	matched 3-to-1	matched 3-to-1	matched 3-to-1	matched 3-to-1	matched 3-to-1	matched 3-to-1
Pre-treat mean	0.687	0.026	0.267	0.71	0.036	0.221

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Standard errors are clustered at the property level.

Table S.7. Estimates of subsidy impact for all landowners receiving payment versus those who do not follow-through

Outcome	All compliers			Noncompliers		
	Tree cover	Crop	Grassland	Tree cover	Crop	Grassland
	(1)	(2)	(3)	(4)	(5)	(6)
Intensity	0.01355**	-0.00344	-0.0097*	4e-04	-0.00491**	0.00517
	(0.00521)	(0.00217)	(0.00527)	(0.00353)	(0.00218)	(0.00405)
Num.Obs.	197082	197082	197082	333162	333162	333162
R2	0.974	0.921	0.961	0.971	0.909	0.958
Control group	matched 3-to-1	matched 3-to-1	matched 3-to-1	matched 3-to-1	matched 3-to-1	matched 3-to-1
Pre-treat mean	0.695	0.029	0.252	0.696	0.023	0.258

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Standard errors are clustered at the property level.