Are Payments for Forest Conservation a Cost-Effective Way to Fight Climate Change? A Meta-Analysis

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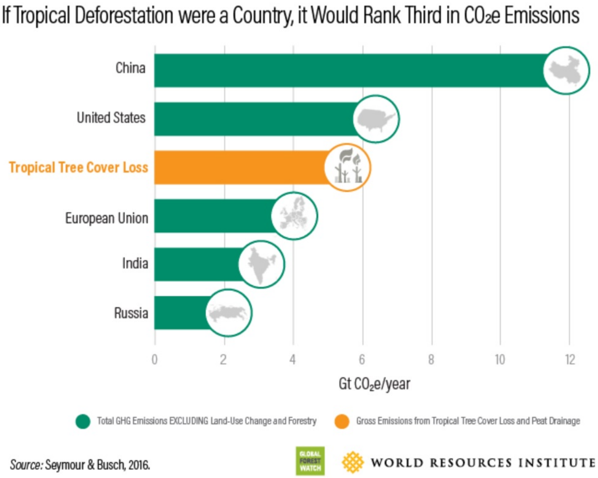
November 2023

Importance



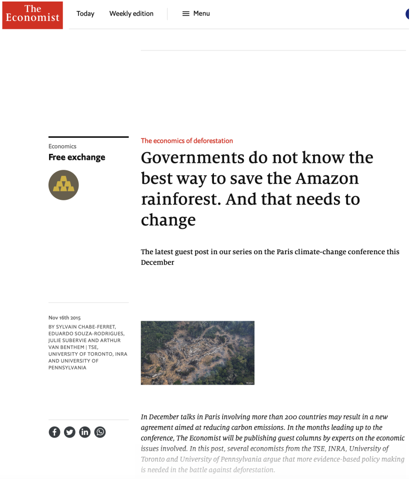
$\Longrightarrow$ **Programs that pay landowners not to cut their standing forest might be an effective way to combat climate change.**

How Does Deforestation Emit CO_2?

Payments for Forest Conservation

- 2 to 20-years voluntary contracts between public or private buyers (e.g. national governments and international organizations) and individual landowners or small communities
- A yearly payment is given conditionally on maintaining all or a part of the forested area owned
- Can have local/national objectives (hydrological services and erosion control) or global (carbon sequestration and biodiversity conservation)
- There are 426 such programs in 57 developing countries

Context in 2015


The Economist
Today
Weekly edition
Menu

Economics
Free exchange

The economics of deforestation

Governments do not know the best way to save the Amazon rainforest. And that needs to change

The latest guest post in our series on the Paris climate-change conference this December

Nov 16th 2015
BY SYLVAIN CHABE-FERRET, EDUARDO SOUZA-RODRIGUES, JULIE SUBERVIE AND ARTHUR VAN BENTHEM | TSE, UNIVERSITY OF TORONTO, INRA AND UNIVERSITY OF PENNSYLVANIA

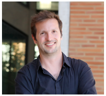
In December talks in Paris involving more than 200 countries may result in a new agreement aimed at reducing carbon emissions. In the months leading up to the conference, The Economist will be publishing guest columns by experts on the economic issues involved. In this post, several economists from the TSE, INRA, University of Toronto and University of Pennsylvania argue that more evidence-based policy making is needed in the battle against deforestation.


Arthur


Julie


Eduardo


Seema


Sylvain

Situation in 2019

RESEARCH ARTICLE

ECONOMICS

Cash for carbon: A randomized trial of payments for ecosystem services to reduce deforestation

Seema Jayachandran,[1]* Joost de Laat,[2] Eric F. Lambin,[3,4] Charlotte Y. Stanton,[5] Robin Audy,[6] Nancy E. Thomas[7]

We evaluated a program of payments for ecosystem services in Uganda that offered forest-owning households annual payments of 70,000 Ugandan shillings per hectare if they conserved their forest. The program was implemented as a randomized controlled trial in 121 villages, 60 of which received the program for 2 years. The primary outcome was the change in land area covered by trees, measured by classifying high-resolution satellite imagery. We found that tree cover declined by 4.2% during the study period in treatment villages, compared to 9.1% in control villages. We found no evidence that enrollees shifted their deforestation to nearby land. We valued the delayed carbon dioxide emissions and found that this program benefit is 2.4 times as large as the program costs.

Effectiveness of a REDD+ Project in Reducing Deforestation in the Brazilian Amazon

Gabriela Simonet, Julie Subervie, Driss Ezzine-de-Blas, Marina Cromberg, and Amy E. Duchelle

We estimate the early effects of the pilot project to Reduce Emissions from Deforestation and forest Degradation (REDD+) in the Brazilian Amazon. This project offers a mix of interventions, including conditional payments, to reduce deforestation by smallholders who depend on swidden agriculture and extensive cattle ranching. We collected original data from 181 individual farmers. We use difference-in-difference (DID) and DID-matching approaches and find evidence that supports our identification strategy. We estimate that an average of 4 ha of forest were saved on each participating farm in 2014, and that this conservation came at the expense of pastures rather than croplands. This amounts to a decrease in the deforestation rate of about 50%. We find no evidence of within-community spillovers.

Bombshell study in 2023

RESEARCH ARTICLE | CARBON OFFSETS

Action needed to make carbon offsets from forest conservation work for climate change mitigation

THALES A. P. WEST, SVEN WUNDER, ERIN O. SILLS, JAN BÖRNER, SAMI W. RIFAI, ALEXANDRA N. NEIDERMEIER, GABRIEL P. FREY, AND ANDREAS KONTOLEON Authors Info & Affiliations

SCIENCE • 24 Aug 2023 • Vol 381, Issue 6660 • pp. 873-877 • DOI: 10.1126/science.ade3535

Editor's summary

Reducing emissions from deforestation and forest degradation (REDD) projects are intended to decrease carbon emissions from forests to offset other carbon emissions and are often claimed as credits to be used in calculating carbon emission budgets. West *et al.* compared the actual effects of these projects with measurable baseline values and found that most of them have not reduced deforestation significantly, and those that did had benefits substantially lower than claimed (see the Perspective by Jones and Lewis). Thus, most REDD projects are less beneficial than is often claimed. —H. Jesse Smith

What's going on?

This paper reconciles these seemingly irreconcilable results

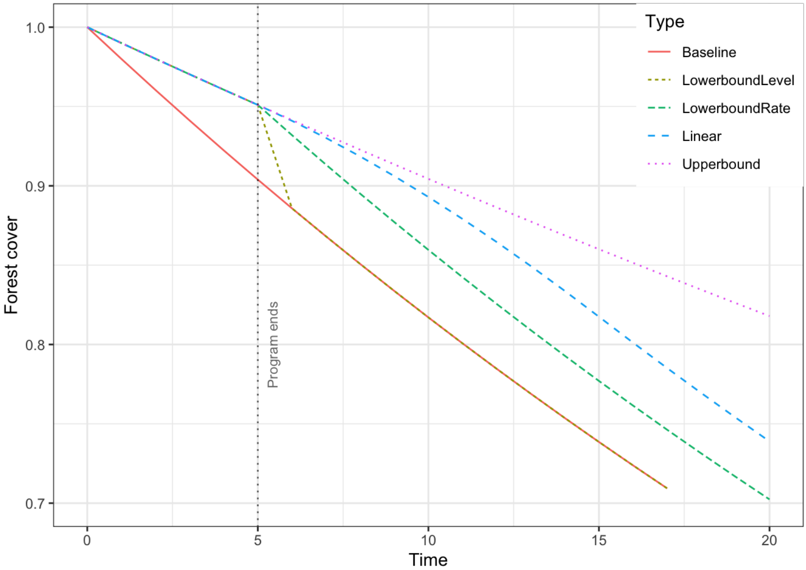
1. Regroup **all** the estimates of additionality of Payments for Forest Conservation programs
2. Investigate sources of heterogeneity

   Methodology
   - Measure of forest cover
   - Access to cadastre data
   - Accounting for leakage effects
   - Econometric method (matching, DID, RCT)
   - Publication bias

   Implementation
   - Governance
   - Payments

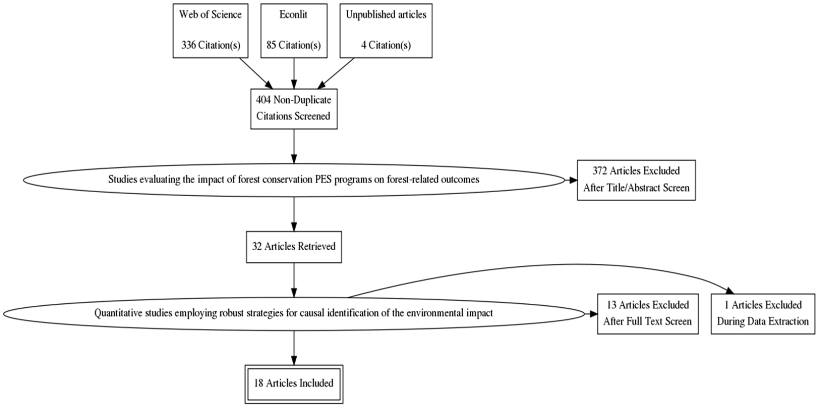
   Context
   - Baseline deforestation
3. Compute benefits and costs

Counterfactual forest cover and program impact



Literature Search

Key words example: payments for ecosystem services AND forest AND (matching OR DID OR RDD OR RCT OR IV)

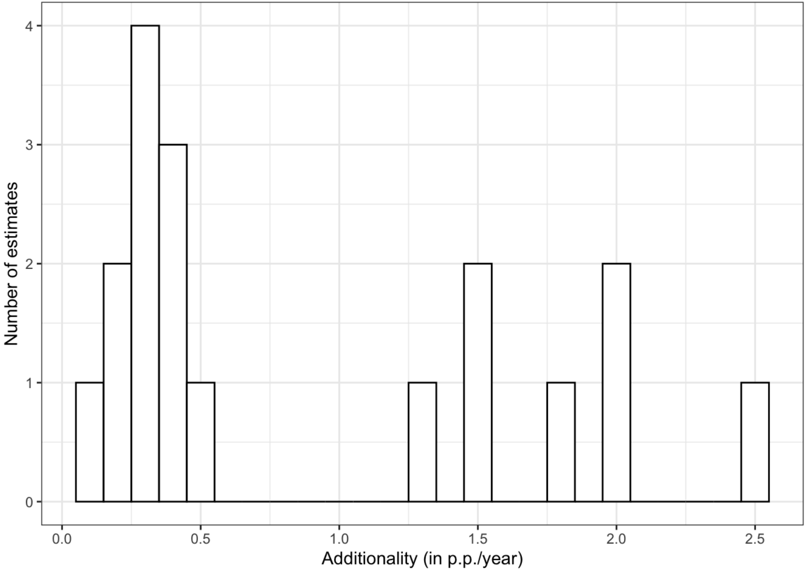


Included Studies

- 10 Forest Conservation Programs in 7 developing countries;

- 2 RCTs and 16 matching (8 matching + DID) evaluation method;
- outcome measured using satellite images;
- one treatment effect from each study ⇒ 18 observations.

Additionality estimates



Method: random effects meta-analysis

$$\hat{\theta}_k = \theta + X_k\beta + \epsilon_k + \nu_k,$$

with

- Measurement error: $\epsilon_k \sim \mathcal{N}(0, \hat{\sigma}_k^2)$
- Effect heterogeneity: $\tau \sim \mathcal{N}(0, \tau^2)$

Method: intuition without regressors

$$\hat{\theta} = \sum_{k=1}^{N} w_k \hat{\theta}_k \text{ with } w_k = \frac{\frac{1}{\hat{\sigma}_k^2 + \hat{\tau}^2}}{\sum_{k=1}^{N} \frac{1}{\hat{\sigma}_k^2 + \hat{\tau}^2}}.$$

- Fixed effects: $\hat{\tau} = 0$
- Random effects: $\hat{\tau} > 0$

We estimate the model using Restricted Maximum Likelihood (see Raudenbusch (2009) and Chabé-Ferret (2023)).

Basic regression

	(1)	(2)	(3)
intercept	0.704***	-0.533*	-0.725***
	(0.171)	(0.238)	(0.219)
N	18	18	18
I^2	97.074	92.638	98.314
τ	0.643	0.913	0.852
Q	175.048	286.593	492.665
p	0.000	0.000	0.000
ATT	0.704	0.891	0.697
ATTse	0.171	0.385	0.266
Outcomes in level	✓		
Outcomes in log		✓	✓
Weights in level	✓		✓
Weights in log		✓	

$+$ p $<$ 0.1, * p $<$ 0.05, ** p $<$ 0.01, *** p $<$ 0.001

Our preferred model

	(1)	(2)	(3)	(4)
intercept	-0.238	-0.386**	-0.386***	-0.445**
	(0.167)	(0.150)	(0.115)	(0.144)
BaselineDeforestation	0.581***	0.603***	0.645***	0.610***
	(0.121)	(0.101)	(0.080)	(0.096)
Cadastre			1.593***	1.516*
			(0.417)	(0.693)
N	15	15	15	15
I^2	72.576	90.478	39.005	89.923
τ	0.497	0.424	0.241	0.395
Q	36.909	179.349	19.405	170.972
p	0.000	0.000	0.079	0.000
ATT	0.892	0.743	0.700	0.701
ATTse	0.247	0.192	0.124	0.142
Outcomes in level				
Outcomes in log	✓	✓	✓	✓
Weights in level		✓		✓
Weights in log	✓		✓	

$+$ p $<$ 0.1, * p $<$ 0.05, ** p $<$ 0.01, *** p $<$ 0.001

Adding discrete controls

	Baseline	Leakage	Matching	Deforestation	National	Government	Park	Collective
intercept	-0.386***	-0.468**	-0.365*	-0.464	-0.258+	-0.323	-0.373*	-0.492*
	(0.115)	(0.173)	(0.166)	(0.330)	(0.146)	(0.242)	(0.147)	(0.203)
BaselineDeforestation	0.645***	0.610***	0.641***	0.669***	0.572***	0.644***	0.642***	0.634***
	(0.080)	(0.097)	(0.089)	(0.126)	(0.093)	(0.083)	(0.085)	(0.082)
Cadastre	1.593***	1.467**	1.578***	1.691**	1.507***	1.610***	1.574***	1.688***
	(0.417)	(0.464)	(0.434)	(0.581)	(0.409)	(0.429)	(0.438)	(0.445)
Leakage		0.175						
		(0.276)						
Matching			-0.050					
			(0.246)					
Deforestation				0.100				
				(0.401)				
National					-0.341			
					(0.277)			
Government						-0.084		
						(0.276)		
Park							-0.044	
							(0.262)	
Collective								0.158
								(0.251)
N	15	15	15	15	15	15	15	15
I^2	39.005	36.714	39.793	35.719	29.413	42.725	42.418	39.346
τ	0.240	0.242	0.272	0.255	0.202	0.261	0.263	0.245
Q	19.405	16.389	17.712	15.853	14.217	19.365	19.038	17.669
p	0.079	0.127	0.089	0.147	0.221	0.055	0.060	0.090

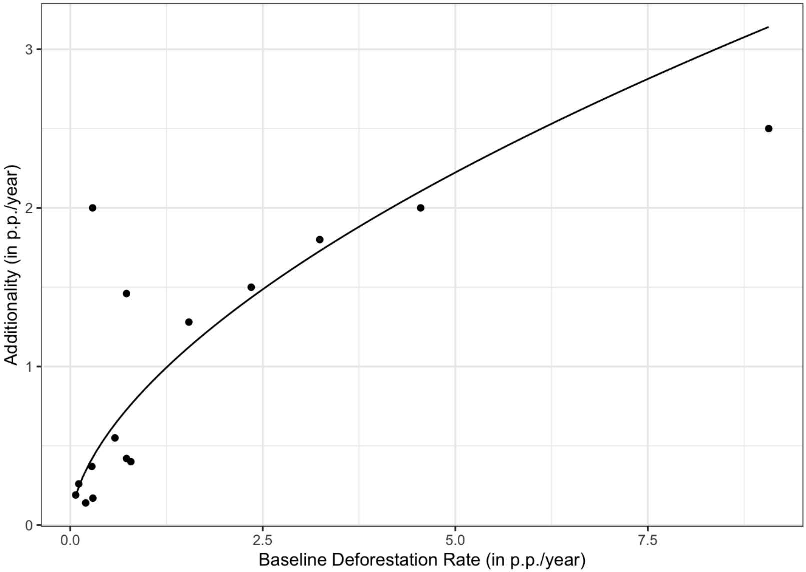
$+$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Adding continuous controls

	Baseline	Payments	Payments per capita	Precision
intercept	-0.386***	-0.260	-0.485	-0.315
	(0.115)	(0.509)	(0.512)	(0.250)
BaselineDeforestation	0.645***	0.645***	0.647***	0.629***
	(0.080)	(0.082)	(0.082)	(0.094)
Cadastre	1.593***	1.609***	1.601***	1.623***
	(0.417)	(0.429)	(0.426)	(0.430)
Payments (USD2010PPP/ha)		-0.035		
		(0.138)		
Payments (share of GDP per capita)			-0.031	
			(0.156)	
Standard error of additionality				-0.241
				(0.750)
N	15	15	15	15
I^2	39.005	42.290	42.327	39.059
τ	0.241	0.257	0.255	0.245
Q	19.405	19.142	19.337	17.809
p	0.079	0.059	0.055	0.086

$+$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Additionality increases with baseline deforestation



Robustness of our main result

Concerns about our main result

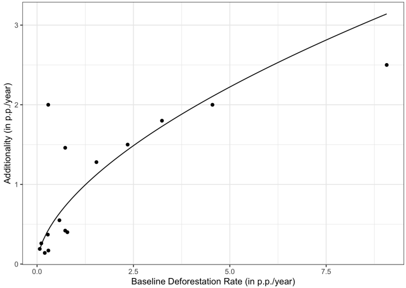
- Maybe we capture a mechanical correlation between $\hat{\theta}_k = \hat{\theta}_k^0 - \theta_k^1$ and $\hat{\theta}_k^0$
- When predicted counterfactual deforestation $\hat{\theta}_k^0$ is low, additionality is mechanically low
- Maybe it's all publication bias

We propose three pieces of evidence that favor our causal interpretation

1. Additionality is bounded above by baseline deforestation
2. Precision of estimated effects decreases with baseline deforestation
3. Our main relationship holds including only studies with the same precision

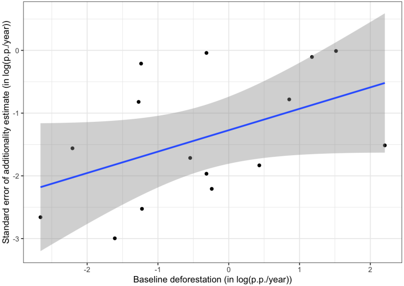
Additionality is bounded above

- Additionality is bounded above by the amount of baseline deforestation
- We should not see additionality higher than baseline deforestation rates
- The only exception is when the authors have access to cadastre data



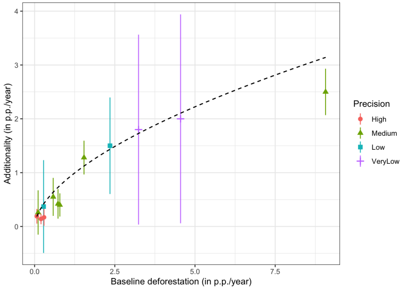
Precision decreases with baseline deforestation

- Larger programs are evaluated with larger sample sizes and higher precision
- Larger programs are also less well-targeted to areas under deforestation pressure
- We should see higher precision where baseline deforestation is low

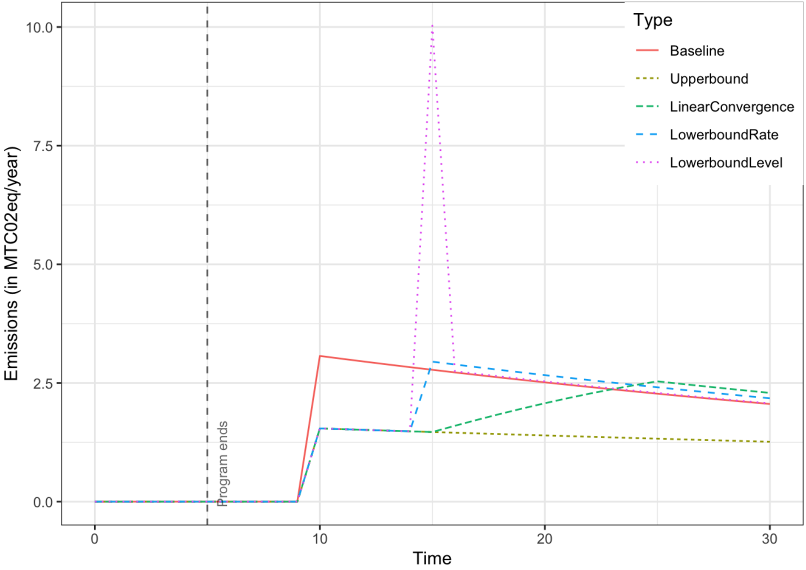


Is it all publication bias?

- Programs with higher baseline deforestation have smaller sample sizes
- We only publish results that are statistically significant
- Additionality is mechanically higher where baseline deforestation is higher
- Our main result should disappear after conditioning on precision



Impact of the program on emissions



Computing climate benefits

$H \in \{U, LR, LL, LC, Steps\}$

$$B_H^c = -\int_0^\infty \left(E^1(t) - E^0(t)\right) SCC(t) e^{-rt} dt$$

$$B_U^c = -GSCCe^{-rT} \left(\frac{1}{1+\frac{r}{k_1}} - \frac{1}{1+\frac{r}{k_0}} \right)$$

$$B_{LR}^c = -GSCCe^{-rT} \left[\left(\frac{1-e^{-(k_1+r)K}}{1+\frac{r}{k_1}} - \frac{1-e^{-(k_0+r)K}}{1+\frac{r}{k_0}} \right) + e^{-rK} \frac{e^{-k_1K} - e^{-k_0K}}{1+\frac{r}{k_0}} \right]$$

$$B_{LL}^c = -GSCCe^{-rT} \left[\left(\frac{1-e^{-(k_1+r)K}}{1+\frac{r}{k_1}} - \frac{1-e^{-(k_0+r)K}}{1+\frac{r}{k_0}} \right) + e^{-rK} \left(e^{-k_1K} - e^{-k_0K} \right) \right]$$

Computing climate benefits (cont'd)

Linear Convergence

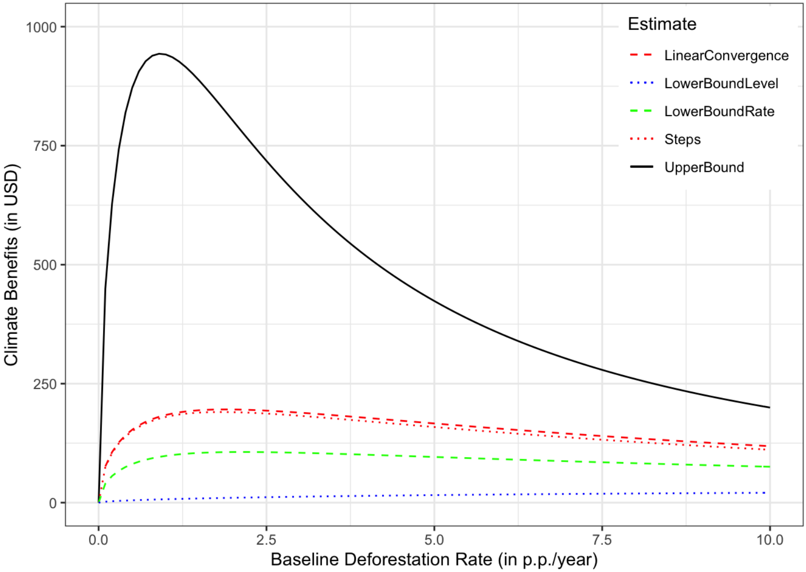
$$
\begin{aligned}
B_{LC}^{c} = & -GSCCe^{-rT}\left(\frac{1-e^{-(k_1+r)K}}{1+\frac{r}{k_1}}-\frac{1-e^{-(k_0+r)K}}{1+\frac{r}{k_0}}\right) \\
& - GSCCe^{-r(T+K)}\Bigg[e^{-k_1 K}\Bigg(\left(1-e^{-(\frac{k_1+k_0}{2}+r)\kappa}\right) \\
& + r\sqrt{\frac{2\pi\kappa}{k_0-k_1}}e^{\frac{\kappa(k_1+r)^2}{2(k_0-k_1)}}\left(\Phi\left(\sqrt{\frac{\kappa}{k_0-k_1}}(k_1+r)\right)\right. \\
& \left.\left.-\Phi\left(\sqrt{\frac{\kappa}{k_0-k_1}}(k_0+r)\right)\right)\Bigg)-e^{-k_0 K}\frac{1-e^{-(k_0+r)\kappa}}{1+\frac{r}{k_0}}\Bigg] \\
& - GSCCe^{-r(T+K+\kappa)}\frac{e^{-(k_1 K+\frac{k_1+k_0}{2}\kappa)}-e^{-k_0(K+\kappa)}}{1+\frac{r}{k_0}}.
\end{aligned}
$$

Computing climate benefits (cont'd)

Stepwise convergence

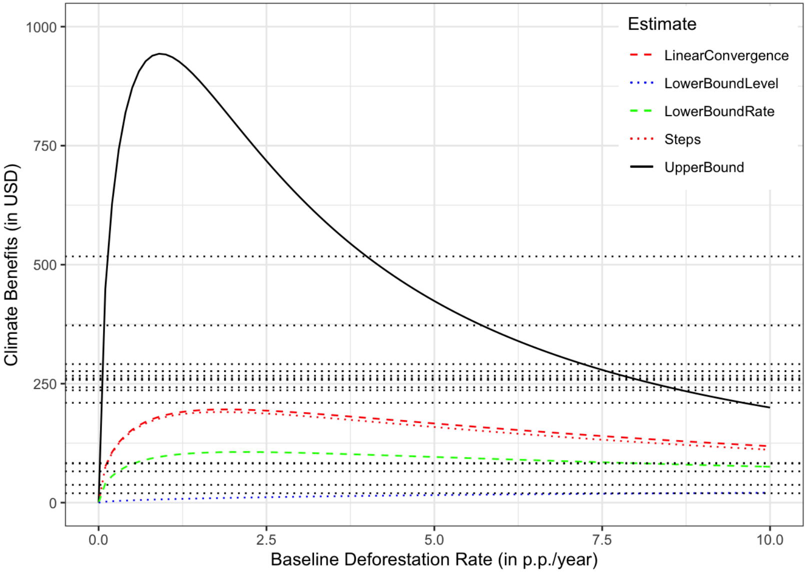
$$
\begin{aligned}
B^c_{Steps} = -GSCCe^{-rT}\left(\frac{1-e^{-(k_1+r)K}}{1+\frac{r}{k_1}} - \frac{1-e^{-(k_0+r)K}}{1+\frac{r}{k_0}}\right) \\
- GSCCe^{-r(T+K)}\left(e^{-k_1 K}\frac{1-e^{-(\frac{k_1+k_0}{2}+r)\kappa}}{1+\frac{r}{\frac{k_1+k_0}{2}}}\right. \\
\left. - e^{-k_0 K}\frac{1-e^{-(k_0+r)\kappa}}{1+\frac{r}{k_0}}\right) \\
- GSCCe^{-r(T+K+\kappa)}\frac{e^{-(k_1 K+\frac{k_1+k_0}{2}\kappa)} - e^{-k_0(K+\kappa)}}{1+\frac{r}{k_0}}
\end{aligned}
$$

Climate benefits depend on baseline deforestation



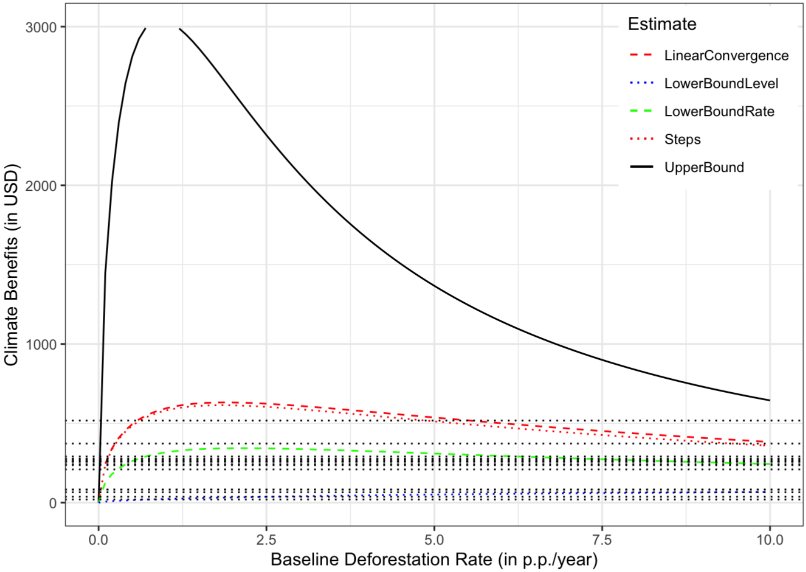
$SCC = 31 USD(2010)/tCO2eq$, Program duration=5 years

Climate benefits *vs* program costs



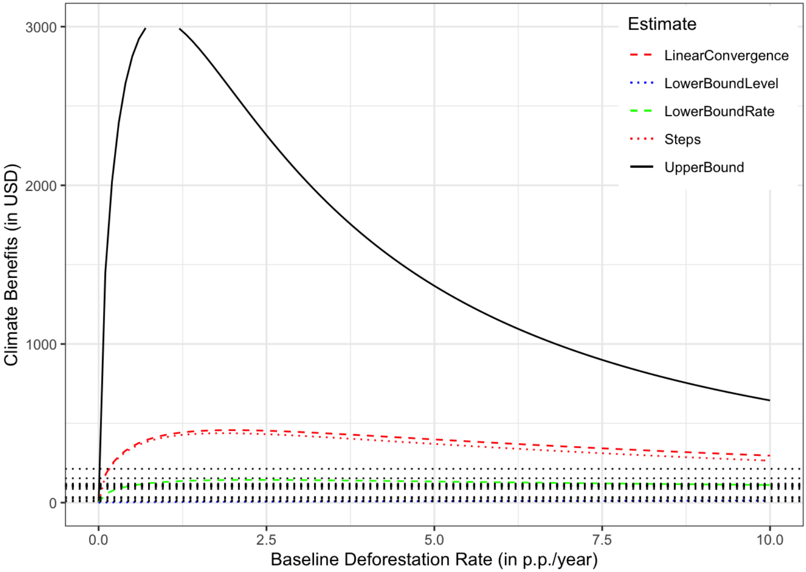
$SCC = 31USD(2010)/tCO2eq$, Program duration=5 years

What if the Social Cost of Carbon is higher?



$SCC = 100 USD(2010)/tCO2eq$, Program duration=5 years

What if programs are shorter?



$SCC = 100USD(2010)/tCO2eq$, Program duration=2 years

Major take-away points

1. Additionality increases with baseline deforestation
   - Similar result for Mexico (Alix-Garcia et al., 2019)
2. Climate benefits critically depend on permanence of impacts
   - At 100USD/tCO2eq, a small amount of permanence makes most programs cost-effective
   - Suggestive recent evidence that permanence exists (Jayachandran et al., 2020; Pagiola et al., 2016)
3. Taking reforestation into account might tremendously increase program impacts, including where deforestation is low
4. No strong signs of leakage
5. No strong signs of publication bias (beyond those acting through baseline deforestation)