Scientific Defense of the Dissertation Project: "Institutional and Fiscal Policies for Forest Conservation"

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September 8, 2017

Overview

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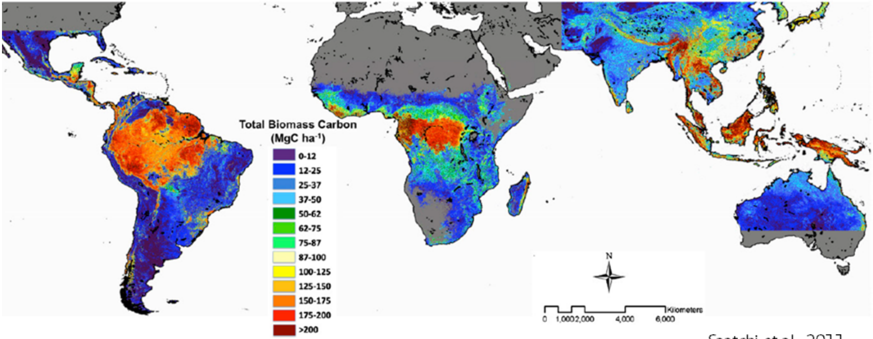
Carbon sequestration as one of the important ecosystem services that forests provide

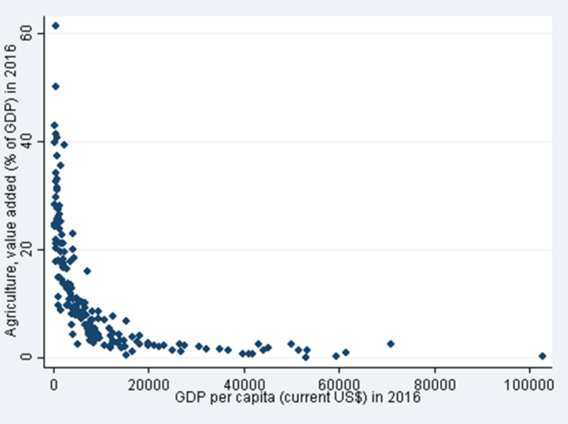


Saatchi et al., 2011

- Ecosystem services: biodiversity, soils, water etc. (Smith et al., 2014).
- Global forests store up to 296 Gt C (FAO, 2016), tropical forests store up to 20 times more C than temperate forests (Saatchi et al., 2011).

Forest conservation and economic development trade-off in low income countries

Undiversified economies have fewer economic alternatives to land demanding agricultural activities (Barbier, 2004).



Data source: World Bank, 2016.

International assistance for forest conservation policies

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- UNEP (2015): Integrated jurisdictional approach is required.
- Jurisdictional approach: Implementation through national or subnational entities.

The role of political institutions in deforestation processes

Wilson et al. 2008; image: Blair J., 2010

Instititutions in the economic analysis of deforestation problems

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- Research on collective action problems: the absence of governance structures makes collective goods rivalrous and non-excludable; individually rational strategies lead to collectively irrational outcomes (Campbell and Sowden, 1985; Ostrom, 1990).
- → Which strategies allow to prevent such collective action problems?

Research projects

- How do political institutions affect deforestation processes?
  - **Wehkamp** J., Koch N., Lübbers S., Fuss S. (2018). Governance and deforestation - a meta-analysis in economics. *Ecological Economics*, 144:214-227.
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Motivation

- A multitude of empirical studies examines the relationship between weak institutions and deforestation (e.g. Deacon, 1994; Bhattarai and Hammig, 2001; Arvin and Lew, 2011; Ehrhardt-Martinez et al., 2002).
- Taking stock of the literature is hampered by substantial heterogeneity in study designs:
  - A broad spectrum of governance measures is used to operationalize the quality of governance (e.g. democracy, ownership security).

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- Taking stock of the literature is hampered by substantial heterogeneity in study designs:
  - A broad spectrum of governance measures is used to operationalize the quality of governance (e.g. democracy, ownership security).
  - Different methods (econometric specifications, control variables etc.) are deployed to estimate the effect.

Research questions

- Why do some studies find supportive evidence for the hypothesis that governance reduces deforestation and others not?
- Which factors explain the variations in study outcomes in the empirical literature on governance and deforestation?

Method

- A meta-regression analysis of the empirical literature can reveal the salient sources of variations in study outcomes.

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- β coefficient values, ϵ is the error term.

Results: Governance variables

Moderator variable	Coefficient	Marginal effects		
		Negative	*Inconclusive*	*Positive*
Governance variables				
environmental_policy	1.153*	-0.042**	-0.333**	0.375**
	(0.657)			
ownership	1.264**	-0.044**	-0.355***	0.399***
	(0.494)			
NGOs	2.320***	-0.053**	-0.468***	0.522***
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democracy	-1.011**	0.149	0.226***	-0.375**
	(0.510)			
rights	-1.518***	0.246*	0.286***	-0.532***
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rule_of_law	0.987*	-0.045*	-0.3**	0.345**
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Motivation

- The current state of the art in large scale numerical forest cover change modeling is to combine a detailed representation of biophysical processes with economic decision-making principles.

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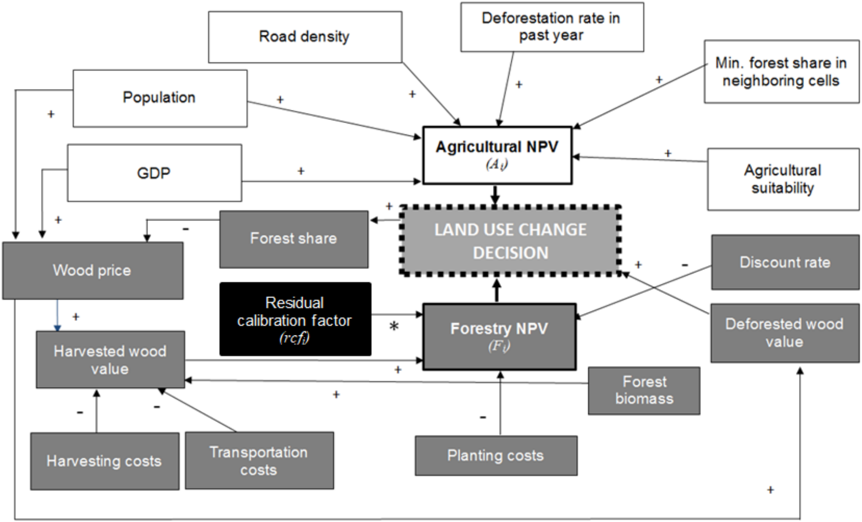
- Wang et al., 2016, Magliocca et al., 2015, and Turner et al., 2016 highlight that human decision making and institutions need to be taken more explicitly into account in ecological modeling.
- The Global Forest Model (G4M global v.4.0) has an economic and a biophysical component (Kindermann, 2006; 2008).

Research question

- Can taking environmental institutions into account help to improve the precision of the global forest model?

Method


Road density
Deforestation rate in past year
Min. forest share in neighboring cells
Population
GDP
Agricultural NPV
(A_i)
Agricultural suitability
LAND USE CHANGE DECISION
Forest share
Wood price
Discount rate
Residual calibration factor
(rcf_i)
Forestry NPV
(F_i)
Deforested wood value
Harvested wood value
Forest biomass
Harvesting costs
Transportation costs
Planting costs
+
-
*

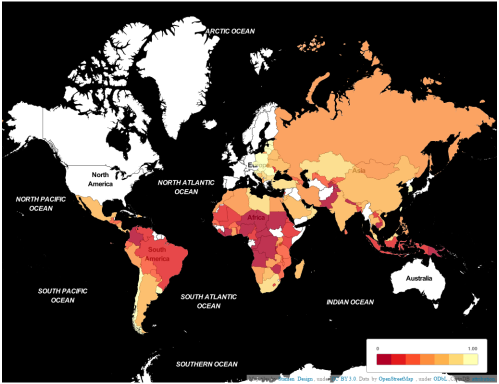
Method

- Index on environmental institutional quality with three components, corresponding to three governance levels:
  - Decision making processes and procedures
  - Environmental policy
  - Enforcement
- OLS regression analysis, in order to analyze, whether the rcf_i can be explained by the index

$$ln(rcf_i) = \beta_0 + \beta_1 EIQ_i + \gamma_j CV_{i,j} + \epsilon_i. \tag{1}$$

- EIQ_i is incorporated into the model, which allows to analyze the percentage reduction of the rcf_i.

Results



- By including the EIQ index into the model, we can reduce the residual calibration factor by on average 43% for the 2000-2010 calibration period.
- First tests for the 2010-2015 calibration period confirm the results.

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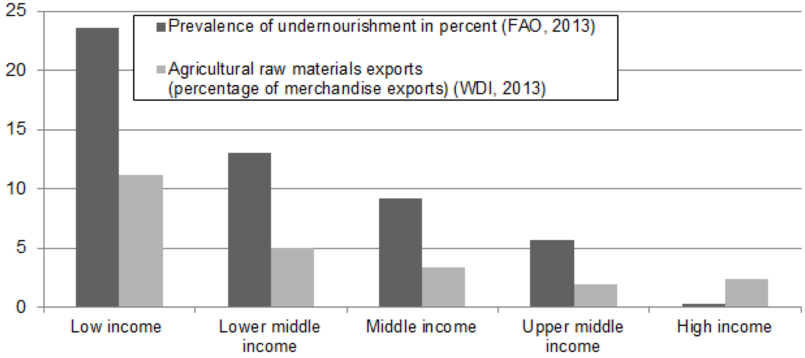
- (3) In countries where insecurity of food supply causes vulnerability to conservation-induced land-use restrictions (Brockington and Igoe, 2006; Oldekop et al., 2016).

Two parallel agricultural sectors



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- Forest conservation is complicated:
- (1) In countries where economic growth is mostly driven by a land-intensive agricultural sector (Kongsamut et al., 2001).
- (2) In institutionally weak countries that are trapped into "undercomplex" economic activities (Nunn and Trefler, 2013).
- (3) In countries that experience insecurity of food supply causes vulnerability to conservation-induced land-use access restrictions (Brockington and Igoe, 2006; Oldekop et al., 2016).
- $\rightarrow$ All factors coincide 1/3 of REDD+ countries.

Research questions

- Which type of policy could allow to reduce deforestation in countries with weak implementing capacities, without negatively impacting production in the exporting sector and without putting domestic food supply at risk?
- Could export tariffs combined with public investments allow to achieve this goal?

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- The government provides a certain amount of public infrastructure and institutions (e.g. electricity, land rights) G and collects an export tariff τ.
- The representative farmer chooses an amount of capital K, land L, and uses a given amount of G as inputs to production Y, such that

$$\max_{K,L}(1-\tau)p(G^{\alpha}K^{\beta}L^{\gamma}) - r_K K - r_L L \,. \tag{2}$$

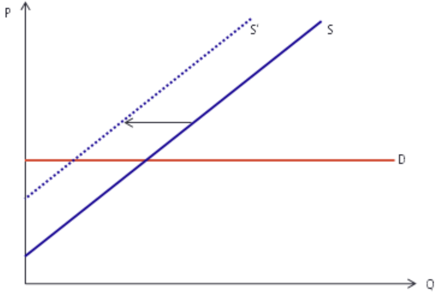
Method: Two agricultural sectors with different elasticities of demand

- Sector 1 (F_1) produces staple food. The local demand for food products is inelastic $\theta_1 = 0$.
- Sector 2 (F_2) exports internationally. Demand is perfectly elastic $\theta_2 = \infty$ and determined by international market prices p_2.

Food producing sector ($\theta = 0$)   Exporting sector ($\theta = \infty$)

Results: Effect of a tariff increase on the exporting sector

By equalizing the land prices of both sectors the equilibrium effects can be analyzed.



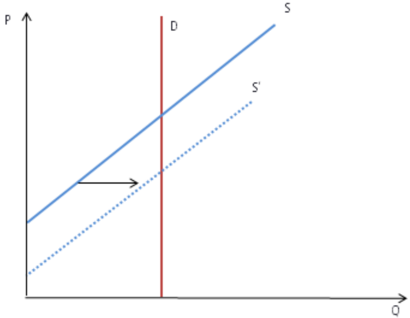
Decrease in input use in the exporting sector $\frac{dL_2}{d\tau} < 0$

$\downarrow$

Decrease in deforestation

Decrease in production in exporting sector $\frac{dY_2}{d\tau} < 0$

Results: Effect of a tariff increase on the food producing sector



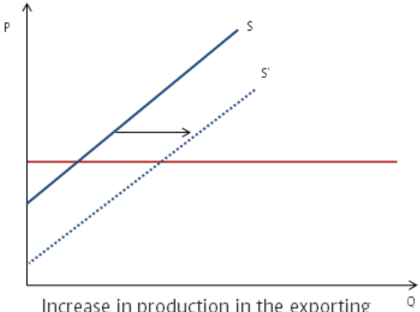
Decrease in prices in the food producing sector
$\frac{dp_1}{d\tau} < 0$

Decrease in land price in the food producing sector → increase in land use $\frac{dL_1}{d\tau} > 0$

↓

Increase in deforestation

Results: Effects of public investments on the exporting sector (Jevons effect)



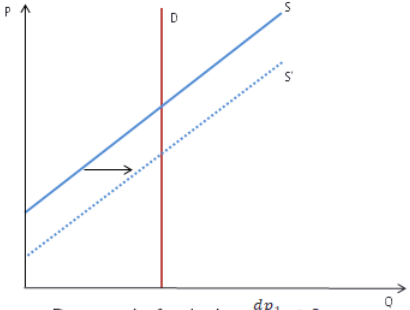
Increase in production in the exporting sector $\frac{\partial Y_2}{\partial G} > 0$

Increase in input use in the exporting sector $\frac{dL_2}{d\tau} < 0$

↓

Increase in deforestation

Results: Effect of public investments on the food producing sector (Borlaug effect)



Decrease in food prices $\frac{dp_1}{dG} < 0$

Decrease in input demand due to a substitution effect $\frac{dL_1}{dG} < 0$

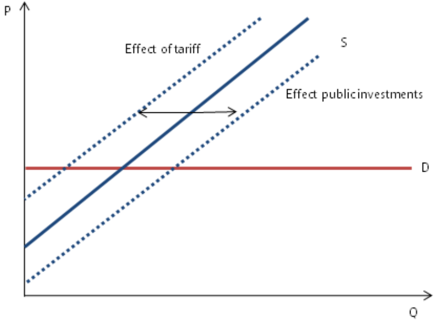
↓

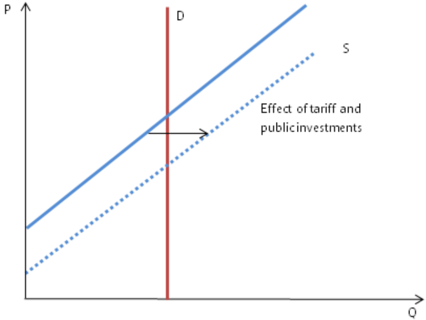
Decrease in deforestation

Stakeholder constraints

- **Government**: accepts no additional public expenditures for forest conservation
- **Exporting sector**: wants to maintain production
- **Food producing sector**: wants to maintain production
- **Population**: would not accept an increase in food prices
- **International REDD+ donor**: willing to make a payment, if forests are conserved

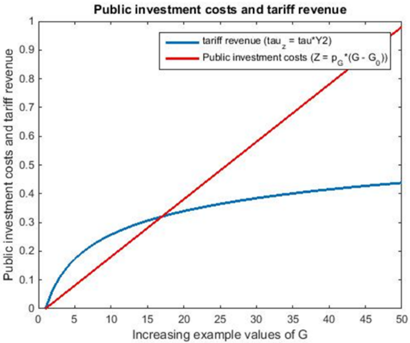
Results: Combining both policies

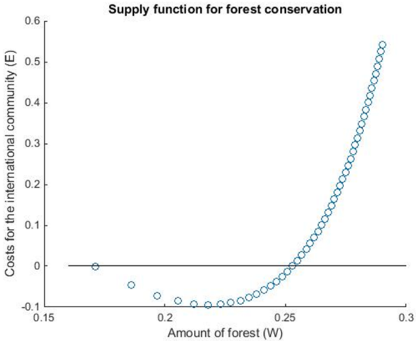




- For any level of G it is possible to raise τ s.t.
  - (i) production in the export sector remains constant
  - (ii) there is a net reduction in deforestation
  - (iii) food prices decline

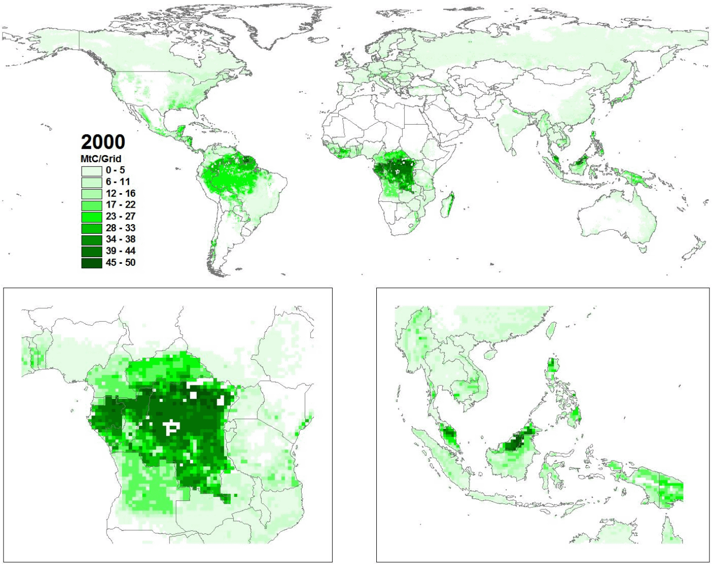
Results: Numerical example





Overview

Mt C per grid cell in the Global Forest Model (G4M)



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- The findings show that specific environmental governance metrics tend to lead to a decrease in deforestation consistently across studies.
- In contrast to existing studies that use general governance indicators (e.g. Wang et al. 2016, Benítez et al., 2007), G4M analysis uses a specific indicator measuring the quality of environmental governance.
- Competing land use model takes the specific structural characteristics of institutionally weak countries, notably the representation of two distinct agricultural sectors into account.

Limitations

- Literature is rich in criticism of general governance measures (Kaufmann and Kraay, 2008; Devarjan, 2008; Kurtz and Schrank, 2007; Kishor and Belle, 2004) and analysis with more specific governance measures are only emerging.

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- Future research could build on the metrics identified in the content analysis project (Wehkamp et al., 2015) in order to use more refined proxies.
- The competing land use model could be calibrated to a specific country context.

Policy implications

- Institutions are a central parameter in determining whether a country can reduce its deforestation.
- How could jurisdictional REDD+ activities that target structural drivers of deforestation be financed in the future?
- Could jurisdictional REDD+ be financed by carbon markets in the future?

Thank you for your attention!

PhD candidate: Johanna Wehkamp
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Mercator Research Institute on Global Commons and Climate Change gGmbH (MCC)
Technical University of Berlin (TU)

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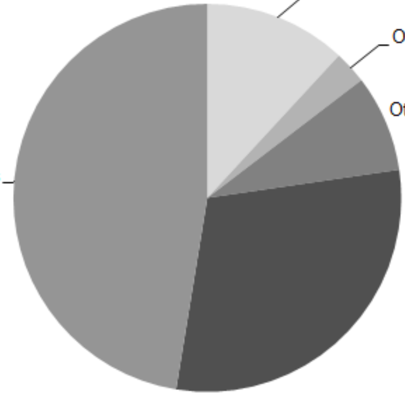
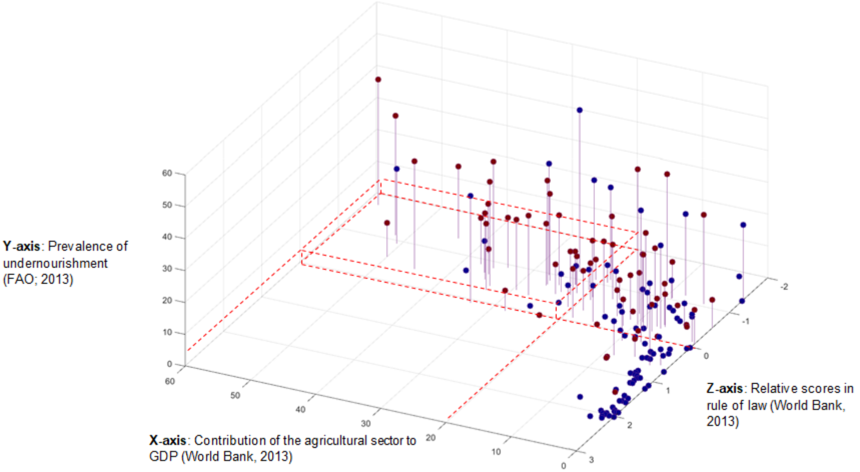
Appendix I

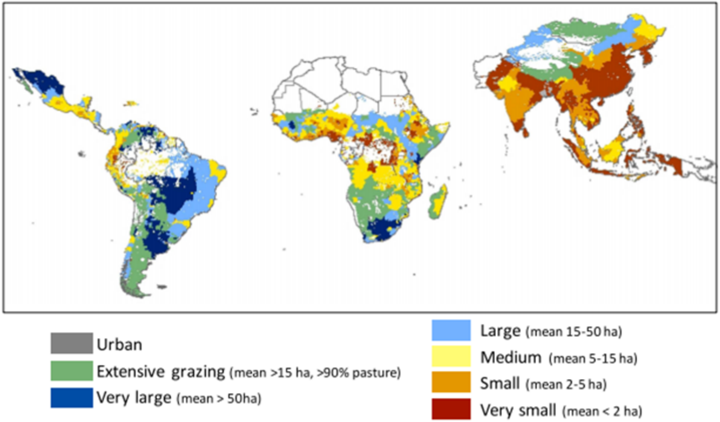
Share of forests in most vulnerable countries



Structural constraints to forest conservation policies coincide in REDD+ countries



Inequality in land ownership

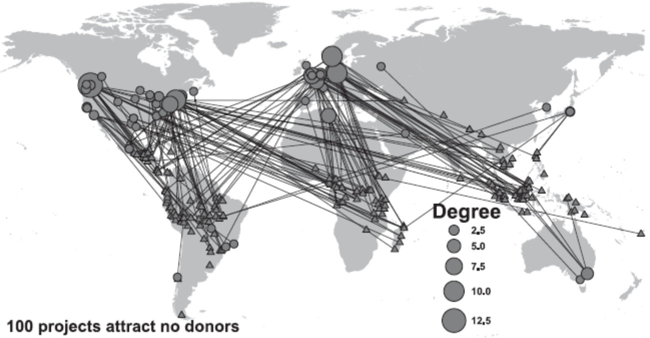


Meyfroidt et al., 2016

Strategies to fight corruption

- Mandatory open-access documentations of budgeting accounting and public procurement processes (OECD, 2016).
- Freedom of information laws (Ackerman and Sandoval-Ballesteros, 2006).
- Institutionalized, anonymous corruption disclosure mechanisms (Lavena, 2016).
- Better enforcement strategies (Brooks et al., 2013).

Gallemore et al. (2016): Use an exponential random graph model to analyze the effect of information assymetry on donor choice of partner



- They find that REDD+ transactions are more influenced by previous collaboration and brokerage, than project quality (e.g. carbon density).

Definition political institutions and governance

- Kaufmann and Kraay (2008) use institutional quality, institutional capacity, and governance as interchangeable concepts, which can be defined as the traditions and mechanisms through which political authority is exercised in a country.

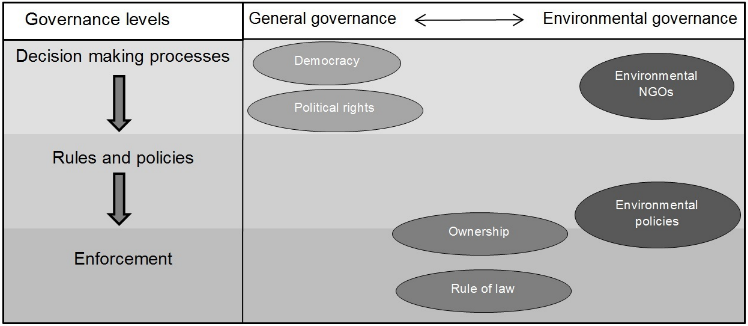
Role of institutions in economic literature

- **Climate Change Economics**
  - Collective action problems (individually rational behavior leads to collectively irrational outcomes (Campbell and Sowden, 1985)).
  - Common pool resource problems in the forest context (Ostrom, 1990).
  - Discussion of policy options offering ways out of non-cooperative equilibria among counties and across generations (Goulder and Pizer, 2006; Stern, 2006).
  - Deforestation as an externality problem (Coase, 1960)
  - New institutional economics literature (Williamson, 1975)
- **Development Economics**
  - Diverging patterns of economic specialization and economic growth.
  - The role of political institutions in economic development processes (Acemoglu, 2001)
  - Bureaucracy literature: how does the performance of a bureaucracy affect the economic development of a country? (Cingolani et al., 2015; Rauch and Evans, 2000).
  - Role of the complexity of contracting institutions in economic development processes (Nunn and Trefler, 2013).

Appendix II

Research questions

- In how are study outcomes influenced by
  - (i) the level of governance (decision making processes, rules, or enforcement)?
  - (ii) the specificity of the deployed governance measure (general vs. specific environmental governance variables)?
  - (iii) other methodological study design elements?



Studies included into the analysis

Author	Year	Number of estimates
Arcand J.L., Guillaumont P., Jeanneney Guillaumont S.	(2008)	12
Arvin B.M., Lew B.	(2011)	12
Barbier E., Damania R., Léonard D.	(2005)	4
Bhattarai M., Hammig M.	(2001)	3
Bohn H, Deacon R.T.	(2000)	1
Buitenzorgy M., Mol A P.J.	(2011)	4
Culas R. J.	(2007)	3
Damette O., Delacote P.	(2012)	15
Damette O., Delacote P.	(2011)	14
Deacon R.T.	(1994)	5
Deacon R.T.	(1999)	4
Didia D.O.	(1997)	2
Ehrhardt-Martinez K.	(1998)	3
Ehrhardt-Martinez K., Crenshaw E.M., Jenkins J.C.	(2002)	4
Ferreira S.	(2004)	5
Ferreira S., Vincent J.R.	(2010)	3
Galinato G., Galinato S.	(2013)	7
Jorgenson A. K.	(2008)	3
Kishor N., Belle A.	(2004)	6
Kuusela O.P, Amacher G.S.	(2016)	3
Li Q., Reuveny R.	(2006)	9
Mainardi S.	(1998)	1
Marchand S.	(2011)	25
Marchand S., Diarra G.	(2011)	6
Marquart-Pyatt S.	(2004)	5
Nguyen V. P., Azomahou T.	(2007)	1
Novoa D. C.	(2008)	22
Rock M.T.	(1996)	2
Shandra J.M.	(2007a)	14
Shandra J.M.	(2007b)	15
Tole L.	(2004)	9
Wolfersberger J., Delacote P., Garcia S.	(2015)	5

Details on the identification of the study population

Search databases	Keywords (as of the 16.2.2016)	Search specification	Date of search	Exportable entries	Final relevant entries
Econ Papers	deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical")	no further specification	21.02.2016	29	3
ScienceDirect (Economics, Econometrics and Finance)	deforestation AND ("governance"OR "institutions") AND ("regression" OR "empirical")	- Search criteria: Deforestation AND ("governance" OR "institutions") AND ("regression" or "empirical") - Economics, Econometrics and Finance - Type: Article - Time selection: All years	21.02.2016	692	7
Wiley (simple search)	deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical")	- Specification: article	21.02.2016	29	0
JSTOR (journals)	deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical")	- Search criteria: Deforestation AND ("governance" OR "institutions") AND ("regression" or "empirical") - Item type: Articles - Discipline and or journal: Economics - All years	21.02.2016	330	4
Springer	deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical")	- Deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical") - Discipline: Economics - Language: English	21.02.2016	427	4
SSRN	deforestation governance institutions	- Deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical") - Did not yield any results. Consequently, we use "deforestation governance institutions".	21.02.2016	3	0
SAGE Journals	deforestation AND ("governance" OR "institutions") AND ("regression" OR "empirical")	- Specification: Economics and Development	29.02.2016	74	0
Taylor and Francis	deforestation AND ("governance"OR "institutions") AND ("regression" OR "empirical")	- Specification: Journal - Specification: Areas Economics, Finance - Business & Industry - Environment and Sustainability	29.02.2016	156	3
Choumert et al. 2013	-		29.02.2016	77	9
Angelsen and Kaimowitz, 1998.	-		29.02.2016	27	2

Sampling strategy

Author	Year	Number of estimates
Arcand J.L., Guillaumont P., Jeanneney Guillaumont S.	(2008)	12
Arvin B.M., Lew B.	(2011)	12
Barbier E., Damania R., Léonard D.	(2005)	4
Bhattarai M., Hammig M.	(2001)	3
Bohn H, Deacon R.T.	(2000)	1
Buitenzorgy M., Mol A P.J.	(2011)	4
Culas R. J.	(2007)	3
Damette O., Delacote P.	(2012)	15
Damette O., Delacote P.	(2011)	14
Deacon R.T.	(1994)	5
Deacon R.T.	(1999)	4
Didia D.O.	(1997)	2
Ehrhardt-Martinez K.	(1998)	3
Ehrhardt-Martinez K., Crenshaw E.M., Jenkins J.C.	(2002)	4
Ferreira S.	(2004)	5
Ferreira S., Vincent J.R.	(2010)	3
Galinato G., Galinato S.	(2013)	7
Jorgenson A. K.	(2008)	3
Kishor N., Belle A.	(2004)	6
Kuusela O.P, Amacher G.S.	(2016)	3
Li Q., Reuveny R.	(2006)	9
Mainardi S.	(1998)	1
Marchand S.	(2011)	25
Marchand S., Diarra G.	(2011)	6
Marquart-Pyatt S.	(2004)	5
Nguyen V. P., Azomahou T.	(2007)	1
Novoa D. C.	(2008)	22
Rock M.T.	(1996)	2
Shandra J.M.	(2007a)	14
Shandra J.M.	(2007b)	15
Tole L.	(2004)	9
Wolfersberger J., Delacote P., Garcia S.	(2015)	5

Different governance measures initially identified in the sample

Governance variables	Number of estimates
Environmental policy	9
Rule of law	36
Quality of the administration	5
Political rights	49
Corruption	18
Democracy	26
Enforcement	4
NGOs	21
International environmental policy	10
Ownership	25
Inequality	14
Stability	4
Environmental compliance	6

Definition of variables and summary of measures

Dependent variable	*Effect category*	*Frequency*	*Percentage*		
	Positive	123	54.19		
	Insignificant	82	36.12		
	Negative	22	9.69		
Moderator variables	*Definition*	*Mean*	*Std. Dev.*	*Min*	*Max*
environmental_policy	Environmental policy	0.11	0.31	0	1
ownership	Ownership and land tenure rights	0.11	0.31	0	1
NGOs	Presence of environmental NGOs	0.09	0.29	0	1
democracy	Democracy	0.11	0.32	0	1
rights	Political rights	0.22	0.41	0	1
rule_of_law	Rule of law and enforcement	0.18	0.38	0	1
population	Population density	0.85	0.35	0	1
income	Income	0.70	0.46	0	1
area	Forest area	0.53	0.50	0	1
timber	Timber	0.36	0.48	0	1
agriculture	Agriculture	0.21	0.41	0	1
developing_countries	Non-high income countries	0.48	0.50	0	1
start	Start year of the analysis	1981.73	11.07	1960	2005
end	End year of the analysis	1998.87	6.00	1985	2010
panel	Panel data	0.45	0.50	0	1
dynamic	Dynamic effects	0.22	0.42	0	1
nonlinear	Non-linear specifications (squared variables, interaction terms)	0.26	0.44	0	1
OLS	Ordinary Least Squares vs. more complex estimators	0.56	0.50	0	1
date	Publication date	2007.60	4.39	1994	2016
size	Sample size	439.39	669.51	20	3441
type	Type of publication	0.74	0.44	0	1

Binary governance moderator variables and effect types

		N	*Proportion of estimates*		
			Negative	Inconclusive	Positive
Governance variables					
environmental_policy	yes	25	0	0.36	0.64
	no	202	0.11	0.36	0.53
	z-value		1.74*	0.01	-1.04
ownership	yes	25	0.04	0.36	0.6
	no	202	0.1	0.36	0.53
	z-value		1.02	0.01	-0.62
NGOs	yes	21	0	0.05	0.95
	no	206	0.11	0.39	0.5
	z-value		1.58	3.14*	-3.96*
democracy	yes	26	0.23	0.42	0.35
	no	201	0.08	0.35	0.57
	z-value		-2.45*	-0.7	2.13*
rights	yes	49	0.2	0.49	0.31
	no	178	0.07	0.33	0.61
	z-value		-2.86*	-2.12*	3.74*
rule_of_law	yes	40	0	0.3	0.7
	no	187	0.12	0.37	0.51
	z-value		2.28*	0.89	-2.21*

Binary control moderator variables and effect types

		N	*Proportion of estimates*		
			Negative	Inconclusive	Positive
Control variables					
population	yes	194	0.1	0.36	0.54
	no	33	0.06	0.36	0.58
	z-value		-0.76	0.03	0.42
income	yes	158	0.09	0.37	0.54
	no	69	0.12	0.35	0.54
	z-value		0.64	-0.28	-0.11
area	yes	120	0.13	0.33	0.55
	no	107	0.07	0.4	0.53
	z-value		-1.51	1.2	-0.26
timber	yes	82	0.06	0.54	0.4
	no	145	0.12	0.26	0.62
	z-value		1.38	-4.14*	3.17*
agriculture	yes	47	0.02	0.32	0.66
	no	180	0.12	0.37	0.51
	z-value		1.97*	0.67	-1.82*

Binary spatial and econometric moderator variables and effect types

		N	Proportion of estimates		
			Negative	Inconclusive	Positive
Spatial and econometric variables					
developing_countries	yes	108	0.12	0.4	0.48
	no	119	0.08	0.33	0.6
	z-value		-1.14	-1.1	1.74*
panel	yes	103	0.08	0.52	0.4
	no	124	0.11	0.23	0.66
	z-value		0.89	-4.66*	3.96*
dynamic	yes	51	0.04	0.59	0.37
	no	176	0.11	0.3	0.59
	z-value		1.58	-3.83*	2.76*
nonlinear	yes	58	0.12	0.4	0.48
	no	169	0.09	0.35	0.56
	z-value		-0.71	-0.65	1.05
OLS	yes	128	0.12	0.26	0.63
	no	99	0.07	0.49	0.43
	z-value		-1.17	3.69*	-2.86*
type	yes	167	0.13	0.35	0.52
	no	60	0.02	0.38	0.6
	z-value		-2.45*	0.42	1.05

Model

- We use an ordered probit model, in order to analyze the effect
- The observed effect categories have a natural ordering (non-supportive (y = 0), insignificant (y=1) and supportive (y=2))
- $y^{\star}$ is the latent continous variable denoting the exact, but unobservable estimated effect size (e.g. not observable how supportive exactly a study is, but when threshold is crossed)
- x is a vector of moderator variables
- β is the vector of all regression coefficients
- ϵ is the error term (with a standard normal distribution)

$$y^{\star} = x * \beta + \epsilon$$

Ordered probit model

- The link between y (a particular effect) and $y^{\star}$ can be specified as following (Greene, 2012), where μ_1 is a threshold parameter
  - $y = 0$ (non-supportive), if $y^{\star} \leq 0$
  - $y = 1$ (inconclusive), if $0 \leq y^{\star} \leq \mu_1$
  - $y = 2$ (supportive), if $\mu_1 \leq y^{\star}$

Ordered probit model

- We use a maximum liklihood estimator, which allows to analyze how a change in a moderator x translate into the probability of observing a particular effect category j.

$$P\left(y=j\right)=\Phi\left(\mu_j-x\beta\right)-\Phi\left(\mu_{j-1}-x\beta\right)\ \textit{for}\ j=0,1,2 \tag{3}$$

  where Φ is the standard normal distribution function, and $\Phi\left(\mu_0-x\beta\right)\equiv 0$ and $\Phi\left(\mu_2-x\beta\right)\equiv 1$.
- The coefficient magnitudes are non-interpretable, because it is a non-linear model, so interpretation is based on sign and significance
- The marginal effect analyses allow to estimate the magnitude of the effect

Results: Governance variables

Moderator variable	Coefficient	Marginal effects		
		Negative	*Inconclusive*	*Positive*
Governance variables				
environmental_policy	1.153*	-0.042**	-0.333**	0.375**
	(0.657)			
ownership	1.264**	-0.044**	-0.355***	0.399***
	(0.494)			
NGOs	2.320***	-0.053**	-0.468***	0.522***
	(0.517)			
democracy	-1.011**	0.149	0.226***	-0.375**
	(0.510)			
rights	-1.518***	0.246*	0.286***	-0.532***
	(0.550)			
rule_of_law	0.987*	-0.045*	-0.3**	0.345**
	(0.519)			

Significance levels: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$

Results on decision-making processes

- When governance is operationalized by the variable democracy the likelihood of finding a supportive outcome is significantly reduced by 38% at a 5% significance level.
- Using the variable political rights even decreases the likelihood of finding a supportive outcome by 53% at a 1% significance level.
- These results do not suggest that more deliberative political processes do not necessarily lead to a reduction in deforestation.
- The literature also discusses the role political instability due to democratic transition phases (which may translate into more deforestation (Buitenzorgy and Mol, 2011; Kuusela and Amacher, 2016).
- *environmental NGOs* shows that strenghtening environmental NGOs is associated with less deforestation (Brazil, soy moratorium).

Results: Control variables

Moderator variable	Coefficient	Marginal effects		
		Negative	*Inconclusive*	*Positive*
Control variables				
population	0.943*	-0.128	-0.227***	0.356**
	(0.490)			
income	0.0904	-0.007	-0.029	0.036
	(0.517)			
area	-1.362***	0.112*	0.386***	-0.498***
	(0.496)			
timber	-0.169	0.013	0.054	-0.067
	(0.330)			
agriculture	0.132	-0.009	-0.043	0.052
	(0.397)			

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Moderator variable	Coefficient	Marginal effects		
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Control variables				
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	(0.330)			
agriculture	0.132	-0.009	-0.043	0.052
	(0.397)			

Results: Control variables

- Including the control variable *population* increases the likelihood of finding supportive results of the governance hypothesis, while including the variable *area* reduces the likelihood.
- *population* variable: could suggest that political institutions are more important, when demographic pressures are high - when population density is low, institutions play a less relevant role.
- *area* variable: Taking into account the existing forest stock, in line with the literature that argues that forest stocks influence deforestation trajectories (forest scarcity path: country only starts to politically control deforestation, if the relative share of forest has become small and forest products scarce (Rudel et al., 2005).

Results: Spatial, temporal, and econometric moderator variables

Moderator variable	Coefficient	Marginal effects		
		Negative	*Inconclusive*	*Positive*
Spatial, temporal and econometric variables				
developing_countries	-0.458	0.036	0.144	-0.18
	(0.386)			
period	0.0534	-0.004	-0.017	0.021
	(0.0467)			
panel	-0.228	0.017	0.073	-0.09
	(0.878)			
dynamic	-0.491	0.047	0.146	-0.194
	(0.707)			
nonlinear	-0.436	0.04	0.132	-0.172
	(0.354)			
OLS	-0.947**	0.069	0.289***	-0.358***
	(0.390)			
date	-0.0736	0.006	0.024	-0.029
	(0.0553)			
type	0.580	-0.057	-0.171	0.228
	(0.640)			
size	0.0148	-0.001	-0.005	0.006
	(0.0210)			
N	227			
Pseudo R2	0.2522			

Results: Spatial, temporal, and econometric moderator variables

- Spatial variable (*developing countries*): variable for non-high income countries remains statistically insignificant.
- Temporal variables (*period*): Exploratory analysis suggested that mroe recent sample periods are more likely to yield positive results, but the multivariate results suggest that the study period has no effect on the probability of the three effect categories.
- Econometrics variables (*panel*, *dynamic*, and *nonlinear*) remain insignificant, suggesting that these technical choices are not a relevant source of variation.

Results: Spatial, temporal, and econometeric moderator variables

- Estimation choice: studies that use *OLS* estimators reduces the probability of finding results that are supportive of the governance hypothesis.
- This result could point at possible measurement errors of the governance variables:
- If the independent variables are subject to measurement errors, the OLS coefficient is more likely to be biased downwards (Wooldridge, 2002).
- There is no clear indication of a publication bias in the results.
- *date*: The effect of the publication year remains statistically insignificant
- *type*: There is no publication bias (published studies are not more or less likely to find a certain outcome) in our sample, but more sophisticated methods could be used in future research.

Robustness tests

	(1) Weigthed [sq(N)]	(2) Weigthed [log(sq(N))]	(3) Probit for significantly positive	(4) Probit for signficantly negative	(5) Four categories
Governance moderator variables					
environmental_policy	0.873	1.042	0.811	0	1.120*
	(0.645)	(0.639)	(0.696)	(.)	(0.678)
ownership	0.593	1.058**	1.656***	-0.0145	1.291***
	(0.569)	(0.492)	(0.447)	(0.844)	(0.494)
democracy	-1.110**	-1.013**	-1.121**	0.750	-0.939*
	(0.533)	(0.499)	(0.551)	(0.585)	(0.491)
NGOs	2.379***	2.328***	1.922***	0	2.450***
	(0.621)	(0.534)	(0.549)	(.)	(0.504)
rights	-1.396***	-1.462***	-1.335**	2.563***	-1.563***
	(0.529)	(0.532)	(0.550)	(0.704)	(0.536)
rule_of_law	0.741	0.912*	0.899*	0	0.984**
	(0.462)	(0.496)	(0.503)	(.)	(0.485)
Control moderator variables					
population	1.113**	1.029**	1.326**	-0.801	0.736
	(0.554)	(0.508)	(0.532)	(0.805)	(0.461)
income	0.611	0.286	0.0221	0.669	0.268
	(0.505)	(0.512)	(0.544)	(0.672)	(0.512)
area	-1.047**	-1.293**	-1.127**	1.271*	-1.328***
	(0.531)	(0.505)	(0.477)	(0.738)	(0.482)
timber	-0.545	-0.275	-0.692**	-1.475**	-0.134
	(0.350)	(0.331)	(0.348)	(0.581)	(0.317)
agriculture	0.337	0.209	-0.0639	-0.881	0.0851
	(0.393)	(0.391)	(0.487)	(0.674)	(0.366)
Spatial, temporal and econometric moderator variables					
developing_countries	-0.739*	-0.528	-0.540	0.893	-0.577
	(0.409)	(0.371)	(0.432)	(0.587)	(0.366)
average	0.0171	0.0415	0.0714*	-0.0180	0.0427
	(0.0470)	(0.0462)	(0.0426)	(0.0575)	(0.0458)
panel	-1.007	-0.467	-0.104	-0.125	0.0631
	(0.884)	(0.860)	(1.015)	(1.196)	(0.840)
dynamic	-0.367	-0.413	-1.114		-0.581
	(0.715)	(0.704)	(0.700)		(0.690)
nonlinear	-0.758**	-0.560	-0.168	1.137*	-0.428
	(0.352)	(0.342)	(0.375)	(0.598)	(0.363)
OLS	-1.076***	-0.935***	-1.028*	1.163	-0.793**
	(0.284)	(0.334)	(0.597)	(0.738)	(0.397)
date	-0.0644	-0.0676	-0.0999*	0.0169	-0.0824
	(0.0567)	(0.0544)	(0.0604)	(0.0708)	(0.0528)
type	-0.267	0.300	0.304	-1.618*	0.454
	(0.681)	(0.645)	(0.635)	(0.927)	(0.638)
size	0.0296	0.0185	0.0110	-0.00840	0.00702
	(0.0219)	(0.0207)	(0.0234)	(0.0225)	(0.0198)
N	227	227	227	141	227
Pseudo R2	0.2525	0.2447	0.3111	0.3597	0.2234

Robustness checks

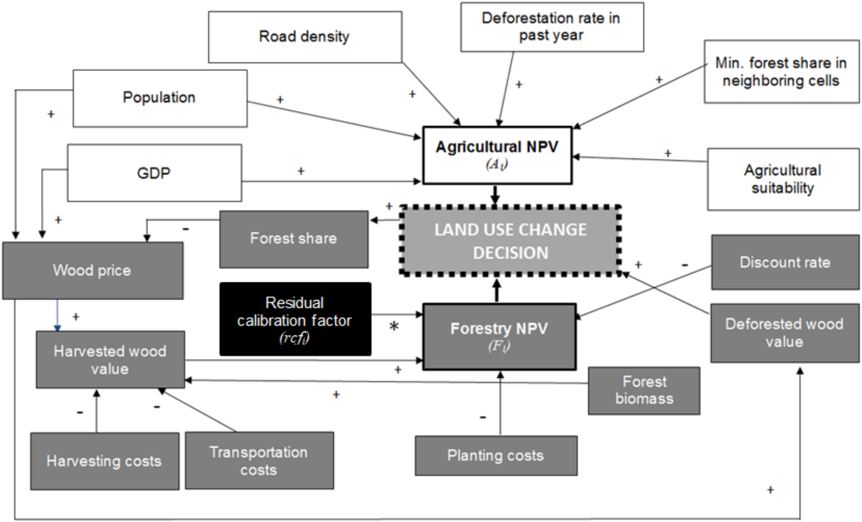
- Risk that there is a mechanical **effect of the sample size** on the distribution of the t-statistics and our dependent variable?
  We use weighted observations using the square root of the sample size (1) and the logarithm of the square root of the sample size (2).
  → Results are consistent with the unweighted estimates.
- **Simple specification test** (Card et al., 2010) estimating separate probit models for the likelihood of significantly positive (3) and significantly negative effect estimates (4) including the square root of the sample size.
  → Both estimated coefficients of interest are small and insignificant.
- Are results influenced by the **number of effect categories**? We use 4 (and not 3) effect categories.
  → Generally no difference, only *population* variable becomes insignificant.

Study limitations: meta-analysis

- We cannot meta-estimate the effect size, but only the direction of causality, hence no information on magnitudes of effects of different variables
- Sample restriction to the field of economics in our study
- Data quality (governance and forest data)

Appendix III

The Global Forest Model (G4M)



Data sources for the composition of the indicator

Indicator	Source	Institution	Availability
Environmental policy	Hartmann and Reimann (2010)	Bertelsmann Foundation	2006-2014
Number of days to start a business	Porter et al. (2008)	World Economic Forum	2003, 2006-2014
	The World Bank Group (2015a)	World Bank Group	2004-2014
Structural constraints	Hartmann and Reimann (2010)	Bertelsmann Foundation	2006-2014

- Policy frameworks: "*environmental policy*" (BTI, 2010)
- Processes/quality of the bureaucracy: "*number of days to start a business*" (World Bank, 2015; Porter et al., 2008)
- Enforcement: "*structural constraints*" (BTI, 2010)

Details on the data sources for the composition of the indicator

- Environmental policy indicator
  - measures "*the extent to which the externalization of costs or inadequate time horizons are avoided or restrained by environmental regulation*" Hartmann and Reimann (2010)
  - Ordinal scales from 0-10
- Number of days to start a business
  - is measured by the number of "*calendar days needed to complete the procedures to legally operate a business*" (Porter et al., 2008).
  - It refers to a standard business that is 100% domestically owned.
  - Data is provided in cardinal units.
- Structural constraints
  - measuring "*structural difficulties* [that] *constrain the political leaderships governance capacity*" (Hartmann and Reimann, 2010; World Bank, 2015). Structural difficulties include "*a lack of educated labor force*" and "*severe infrastructural deficiencies*" (Hartmann and Reimann, 2010).
  - Ordinal scale ranging from 0 to 10.

Details on the construction of the indicator

- Indicator components use different ordinal scales and hence need to be transformed to guarantee homogenous unit of measurement.

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    - For the variables "*number of days to start a business*" and "*structural constraints*" are rescaled, such that for all components of the composite index a high value represents high environmental institutional quality.

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- Average index values are calculated for two periods, corresponding to the two simulation periods of the Global Forest Model, 2000 to 2010 (for the available years) and 2010 to 2015.

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- Average index values are calculated for two periods, corresponding to the two simulation periods of the Global Forest Model, 2000 to 2010 (for the available years) and 2010 to 2015.
- The index is available for a sample of 116 countries (economies in transition, no developed economies, no very small countries, no non-independent territories, no countries with unclear statehood).

The Residual Calibration Factor (RCF)

- The RCF is multiplied with the estimated forest net present value, to match the model's simulation with observed deforestation patterns.

$$F_i, adjusted = rcf * F_i, estimated$$

Regression model

$$ln(rcf_i) = \beta_0 + \beta_1 EIQ_i + CV_i' \gamma_i + \epsilon_i, \tag{4}$$

- EIQ_i is the environmental institutional quality index
- CV is a vector composed of the five control variables identified above (land area, forest cover, population density, GDP, and tropical and subtropical vegetation)
- Semi-logarithmic specification: a one unit increase in environmental institutional quality leads to a percentage increase in the residual calibration factor.
- Different versions of the model are estimated:
    - (i) without control variables
    - (ii) with each single control variable
    - (iii) with all control variables.
- Robustness test: the regressions are also estimated for a restricted range of residual calibration factor values (values between 0.05 and 15).

Ordinary least squares regressions using the logarithm of the residual calibration factor and the index

	logRCF	logRCF	logRCF	logRCF	logRCF	logRCF	logRCF
EIQindex	4.396***	4.836***	5.077***	4.582***	5.108***	5.359***	4.228***
	(3.22)	(4.69)	(4.85)	(3.92)	(4.97)	(5.07)	(3.76)
c_forestcover	-0.00000295		0.00000325				
	(-0.56)		(1.53)				
c_gdpppp	0.0000174			0.00000559			
	(1.03)			(0.44)			
c_landsize	0.00000293				0.00000199*		
	(1.15)				(1.96)		
c_popdensity	-0.000616*					-0.000620*	
	(-1.77)					(-1.88)	
c_tropical	-0.638						-0.865
	(-1.04)						(-1.46)
_cons	-2.581**	-3.089***	-3.301***	-3.031***	-3.393***	-3.260***	-2.044**
	(-2.58)	(-5.46)	(-5.66)	(-5.19)	(-5.85)	(-5.75)	(-2.26)
N	105	112	111	111	112	112	107

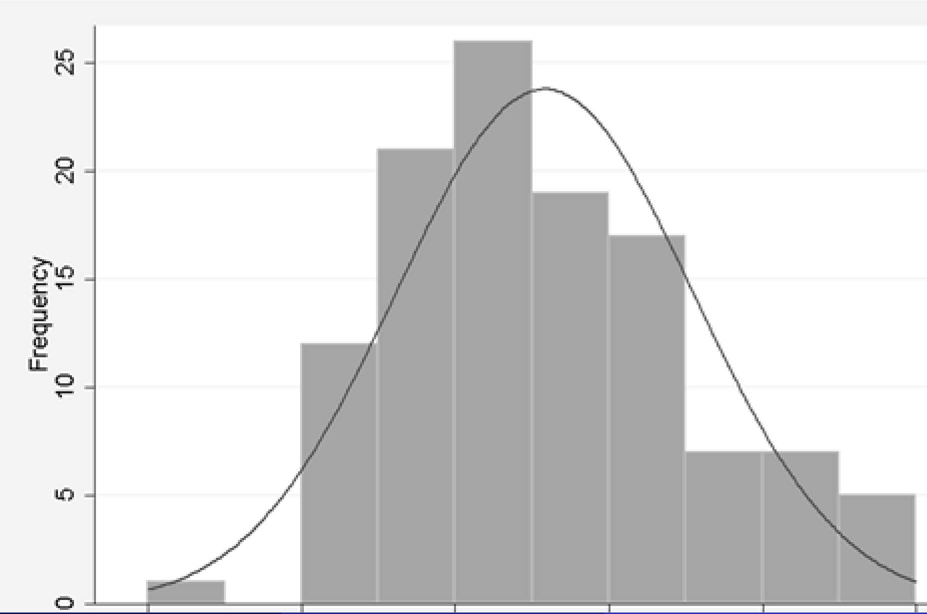
t statistics in parentheses
* $p<0.10$ ** $p<0.05$ *** $p<0.01$

Ordinary least squares regressions using the logarithm of the residual calibration factor and the index for a restricted range of residual calibration factor values (0.05 to 15)

	logRCF	logRCF	logRCF	logRCF	logRCF	logRCF	logRCF
EIQindex	1.652*	1.379**	1.545**	1.193*	1.620**	1.740***	1.261*
	(1.99)	(2.17)	(2.39)	(1.69)	(2.57)	(2.67)	(1.78)
c_forestcover	-0.00000240		0.00000193				
	(-0.81)		(1.64)				
c_gdpppp	0.00000927			0.00000411			
	(0.99)			(0.58)			
c_landsize	0.00000227				0.00000124**		
	(1.58)				(2.23)		
c_popdensity	-0.000392**					-0.000362**	
	(-2.06)					(-2.01)	
c_tropical	0.0470						-0.160
	(0.13)						(-0.45)
_cons	-1.191*	-0.792**	-0.946**	-0.754**	-1.037***	-0.927**	-0.618
	(-1.89)	(-2.15)	(-2.49)	(-2.00)	(-2.75)	(-2.51)	(-1.07)
N	82	88	87	87	88	88	84

t statistics in parentheses
* p<0.10, ** p<0.05, *** p<0.01

Distribution of EIQ values



Unbiasedness of estimator

- Linear in parameters
- Random sample
- Zero conditional mean assumption holds, because we included a range of relevant control variables that could be alternative explanations to the RCF $\rightarrow$ For any x the average μ is the same
- Sample variation in the independent variable
- Homoskedasticity: we also test our model with robust standard errors and conclusions remain unchanged

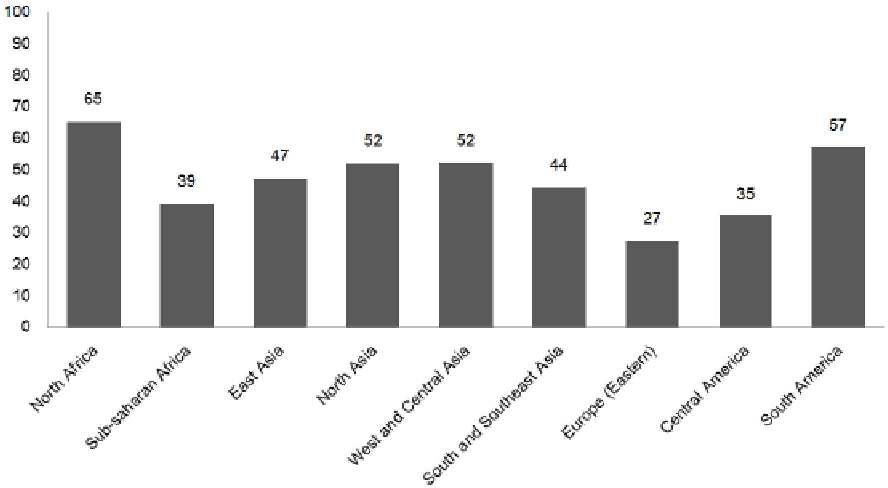
Regression output: index and all control variables

Source	SS	df	MS
Model	128.650873	6	21.4418122
Residual	425.57459	98	4.34259786
Total	554.225463	104	5.32909099

Number of obs	=	105
F(6, 98)	=	4.94
Prob > F	=	0.0002
R-squared	=	0.2321
Adj R-squared	=	0.1851
Root MSE	=	2.0839

ln_RCF	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
norm_h_eiqindex_0010	4.396204	1.366519	3.22	0.002	1.684391	7.108016
Forestcover	-2.95e-06	5.27e-06	-0.56	0.577	-.0000134	7.51e-06
GDPppppc	.0000174	.0000169	1.03	0.306	-.0000162	.0000511
Landsize	2.93e-06	2.55e-06	1.15	0.254	-2.13e-06	7.99e-06
Population_density	-.000616	.0003482	-1.77	0.080	-.0013071	.000075
tropical	-.6382315	.6150267	-1.04	0.302	-1.858732	.5822689
_cons	-2.581452	1.000454	-2.58	0.011	-4.566821	-.5960828

Average reduction of the residual calibration factor



Inclusion of the indicator into the simulation

- The index is incorporated into the model using the following procedure: the adjusted forestry net present value ($F_{i,adjusted}$) is calculated using the estimated forestry net present value multiplied by the "old" residual calibration factor.

$$F_{i,adjusted} = rcf_{old} \cdot F_{i,estimated}. \tag{5}$$

- Values of the rcf_{old} are exponentially distributed. Therefore the logarithm of the residual calibration factor multiplied by the composite index, is equal to the natural logarithm of rcf_{new}

$$ln(rcf_{old}) \cdot EIQ = ln(rcf_{new}). \tag{6}$$

Inclusion of the indicator into the simulation

- It follows that

$$ln(rcf_{old}) = ln(rcf_{new}^{\frac{1}{EIQ}}). \tag{7}$$

- The application of the index to the model provides a measure of the reduction in the residual calibration factor and thus model quality.
- The percent reduction of the residual calibration factor at the country level is then calculated as

$$\%reduction = 100 \cdot (1 - \frac{1 - rcf_{new}}{1 - rcf_{old}}). \tag{8}$$

Appendix IV

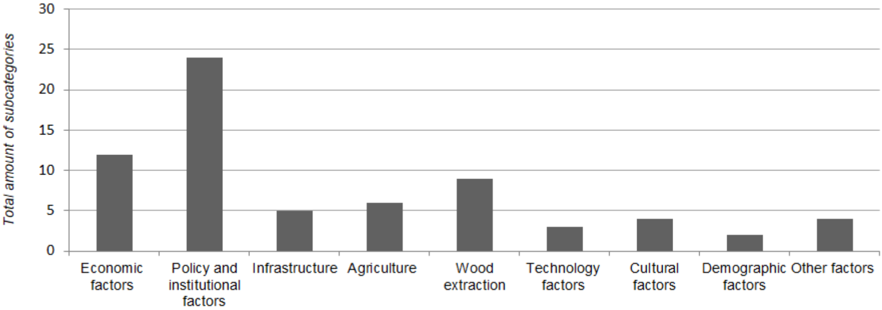
Motivation

- In the implementation phase of REDD+ programs, it becomes crucial to understand deforestation drivers and craft according possible policy responses.
- A majority of the previously identified most vulnerable countries, are located in Subsahara Africa.
- Literature in analyzing deforestation drivers in African countries is severely restricted by the low availability and quality of data (Grainger, 2008; Lewis et al., 2009; Rudel,2013), in particular when it comes to drivers of deforestation that are harder to quantify, define, and measure with usual proxies.

Method

- Forests are theoretically owned by states, thus analyzing the perception of policy makers can be a useful approach to better understand drivers.
- Content analysis can be used to quanitfy the occurence of different concepts in a text.
- The analysis is based on REDD+ policy documents (REDD Readiness Preparation Proposal) of 18 African REDD+ countries.
    - Which deforestation drivers are discussed frequently?
    - Does the perception of drivers provide indications for policy levers to address the drivers?

Results



- African policy makers strongly emphasize institutional and policy drivers of deforestation - in absolute and in relative terms.
- Next to general governance indicators they also describe a range of concrete problems.

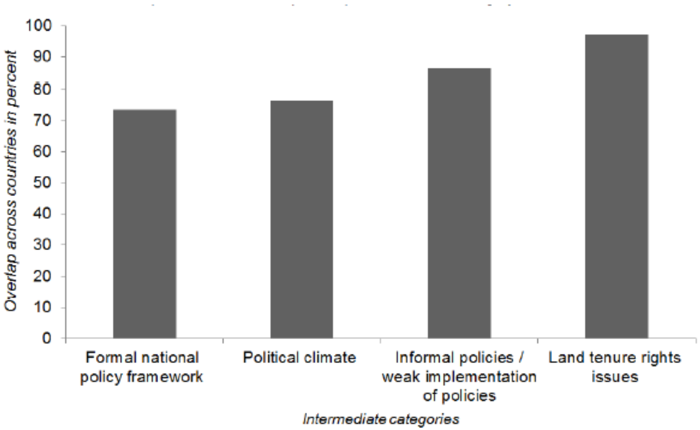
Results and discussion

- Concrete institutional and policy deforestation drivers:
  - Reforms of formal national policy frameworks (inconsistencies between different laws, fiscal policies that incentivize deforestation...)
  - Improvements to political processes (lack of coordination across ministries, information transfer with communities...)
  - Improvement of the implementation of policies (lack of funding for forest monitoring systems, patrolling (no vehicles), lack of scientific knowledge in the forest administration...)
- Contrary to authors that argue that institutional problems are too complex to be addressed through REDD+ (Hall, 2013; Neeff et al., 2014; Chagas et al., 2011), we find that there is a range of very conrete possibly policy levers.
- Concrete entry points that could be used in the REDD+ context to reduce institutional and policy related deforestation drivers.

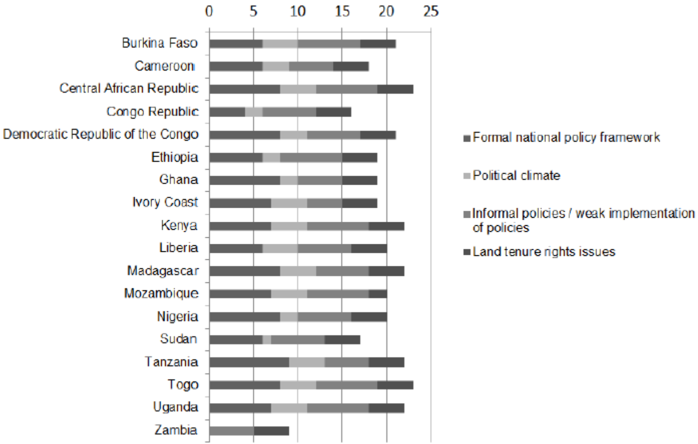
Details on the methodology content analysis

- In the absence of comparable quantitative sources of data, content analysis extracts quantified information (in form of frequencies) from qualitative sources.
- For this paper a content analysis methodology specified by Früh (2007) is used.
- Details of methodological steps
  - (i) Construction of the hypothesis
  - (ii) Selection of sampling material
  - (iii) Development of a category system
  - (iv) Definition of operational units
  - (v) Coding
  - (vi) Intercoder reliability and validity tests

Overlap across countries in percent per intermediate category



Frequencies of subcategories per country, when looking at the intermediate category institutional and policy drivers of deforestation

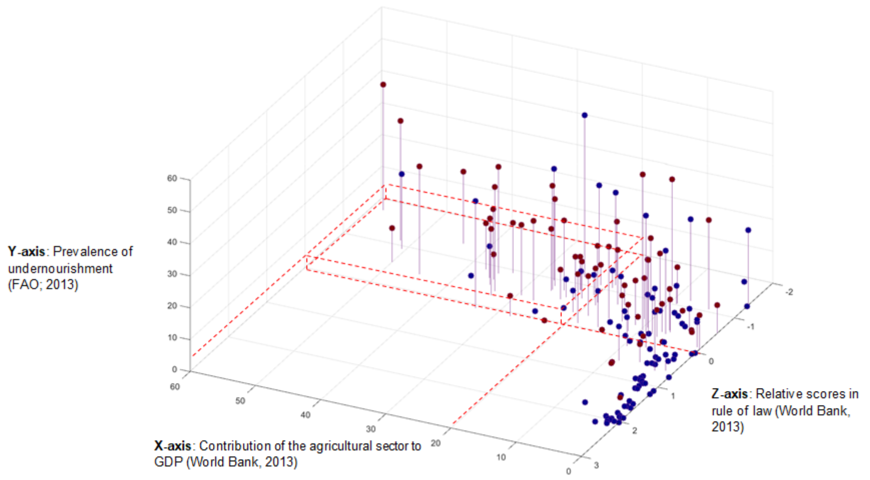


Results and discussion

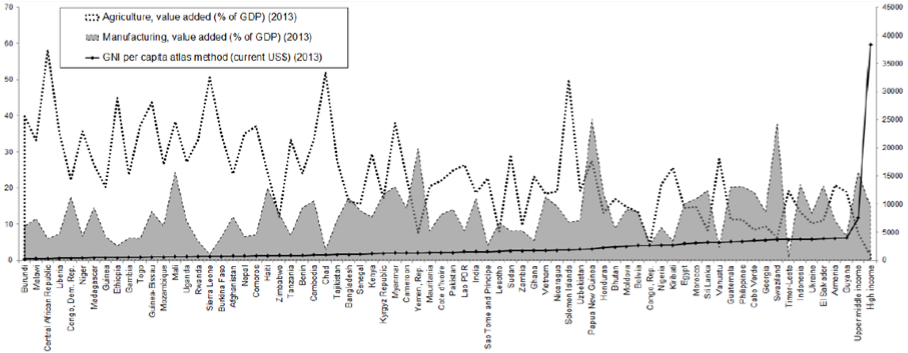
- Institutional and policy drivers of deforestation that African policy makers identify:
  - **Reforms of formal national policy frameworks** (forest policy frameworks, agricultural policy frameworks, industrialization policies, fiscal policies)
  - **Improvements to political processes** (lack of coordination among sectors and policy frameworks, inconsistencies across policy frameworks)
  - **Improvement of the implementation of policies** (lack of knowledge and capacity in the forest administration, lack of ressources and personnel, lack of scientific information on good forest management practices, insufficient distribution of information on legal frameworks, insufficient capacities and technologies to conduct forest monitoring)
- Analysis reveals that there are concrete entry points that could be used in the REDD+ context to reduce institutional and policy related deforestation drivers.

Appendix V

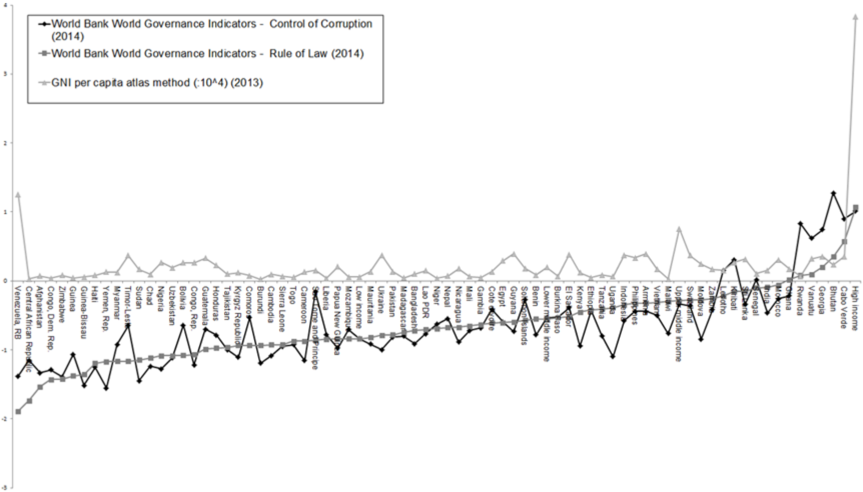
Structural constraints to forest conservation policies coincide in REDD+ countries



Details stylized facts: contribution of the agricultural sector to GDP in low income countries



Details stylized facts: Institutions in low income countries



Export tariffs

- Theoretical (Bernhofen, 1997; Rodrik, 1989) and empirical (Solberg et al., 2010a; Goodland and Daly, 1996) economic literature finds that export tariffs on unprocessed commodities can stimulate the structural transformation of an economy.
- Trade liberalization has accelerated deforestation in tropical countries (Barbier, 2000; Pacheco, 2006; Shandra et al., 2009).
- In the case of timber exports, the introduction of export tariffs has reduced deforestation (Maested, 2001).
- Implementation does not require very sophisticated political institutions (Skinner, 1991; Younger et al., 1999).
- One of the few tolerated trade policy instruments under WTO rules (GATT rule article 2; 11.1 and 11.2 (WTO, 1947).

Public investments

- Investments into institutions bear the potential to reduce deforestation (Culas, 2007; Wolfersberger, 2015).
  - E.g. the allocation of land tenure rights (Mendelssohn, 1994; Robinson et al., 2014)
- Certain types of public infrastructure investments bear the potential to reduce deforestation
  - E.g. electrification (Assuncao et al., 2015)

Maximization problems of the representative farmer

- The representative farmer choses an amount of capital K, land L, and uses a given amount of G as inputs to production Y, such that

$$\max_{K,L} (1-\tau)p(G^{\alpha}K^{\beta}L^{\gamma}) - r_K K - r_L L \; . \tag{9}$$

- This results in the following first order conditions

$$\frac{\partial \mathcal{L}}{\partial K} = (1-\tau)p\beta(G^{\alpha}K^{\beta-1}L^{\gamma}) - r_K = 0 \; , \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial L} = (1-\tau)p\gamma(G^{\alpha}K^{\beta}L^{\gamma-1}) - r_L = 0 \; . \tag{11}$$

Different effect of public investments due to different assumptions on the elasticity of demand

- The amount of land demanded for agriculture is given by

$$L = \left(\gamma^{\beta(-\frac{1}{\theta}+1)-1} (1-\tau)^{\frac{1}{\theta}-1} G^{\alpha(\frac{1}{\theta}-1)} \left(\frac{r_K}{\beta} \right)^{\beta(-\frac{1}{\theta}+1)} \right)^{\frac{\varepsilon}{-\beta(\frac{1}{\theta}-1)-1-\varepsilon\frac{1}{\theta}}} . \tag{12}$$

- An increase in public investments G increases the amount of deforestation if and only if $\theta > 1$.
- **Proof:** We solve the food demand equation (7) for p and the land supply equation (1) for r_L and insert the expressions into the first order conditions (5) and (6). We then solve equation (5) for K and use it to substitute for K in equation (6) and solve for L.

Proposition 1:

- The amount of land demanded for agriculture is given by

$$L = \left(\gamma^{\beta(-\frac{1}{\theta}+1)-1}(1-\tau)^{\frac{1}{\theta}-1}G^{\alpha(\frac{1}{\theta}-1)}\left(\frac{r_K}{\beta}\right)^{\beta(-\frac{1}{\theta}+1)}\right)^{\frac{\varepsilon}{-\beta(\frac{1}{\theta}-1)-1-\varepsilon\frac{1}{\theta}}}. \tag{13}$$

- An increase in public investments G increases the amount of deforestation if and only if $\theta > 1$.

Borlaug case: Demand is perfectly inelastic ($\theta = 0$), $\rightarrow$ public investments decrease deforestation

- Using

$$\lim_{\theta \to 0} \frac{\varepsilon((\frac{1}{\theta} - 1))}{-\beta\frac{1}{\theta} + \beta - 1 - \varepsilon\frac{1}{\theta}} = \frac{\varepsilon}{-\beta - \varepsilon} \tag{14}$$

- As a land demand function we obtain

$$L_1 = \lim_{\theta \to 0} L = \left(\gamma^{-\beta}(1-\tau)G^{\alpha}\left(\frac{r_K}{\beta}\right)^{-\beta}\right)^{\frac{\varepsilon}{-\beta-\varepsilon}} .$$

- From $\frac{\varepsilon}{-\beta-\varepsilon} < 0$ we obtain $\frac{dL_1}{dG} < 0$. □
- The food sector with inelastic demand, thus reflects the Borlaug hypothesis, which postulates that increased agricultural productivity reduces deforestation.
- The Borlaug effect is caused by higher productivity (through more public investments in our case) that allows farmers to produce the same amount of food with less land.

Jevons case: when demand is perfectly elastic ($\theta = \infty$), $\rightarrow$ public investments increase deforestation

- Using $\lim_{\theta \to \infty}$, we can observe that $\frac{1}{\theta} = 0$
- As a land demand function we obtain

$$L_2 = \lim_{\theta \to \infty} L = \left(\gamma^{1-\beta} (1-\tau) G^{\alpha} \left(\frac{r_K}{\beta} \right)^{-\beta} \right)^{\frac{\varepsilon}{1-\beta}} . \qquad (15)$$

- Form $\frac{\varepsilon}{1-\beta} > 0$ we obtain $\frac{dL_2}{dG} > 0$. $\square$
- The export sector, where demand is elastic, reflects the Jevons paradox. Additional public investments makes it more attractive to use the complementary inputs capital and land. The increased use of land in this case accelerates deforestation.

The case of competitive land markets (Proposition 2)

Proposition 2:

- Higher tariffs reduce deforestation, but also production in the export sector.
- They also lead to a reduction in food prices.
- Higher public investments lead to an increase in deforestation and an increase in production in the exporting sector.
- The effect of higher public investments on food prices depends on the relative size of the output elasticity (γ) of public investments in the two sectors.

Summary proof of Proposition 2

- Sector 1 (domestic food producing sector):
  - We have two sectors, whose production levels are determined by the demand function $Y = p^{-\theta}$, where $\theta = \infty$ in the exporting sector and 0 in the food producing sector, s.t. $1 = G^{\alpha_1} K^{\beta_1} L^{\gamma_1}$.
  - In order to see how both sectors behave in equilibrium, we insert the capital-land ratio (K_1/L_1) and have the levels of investment of K_1 und L_1 and the land rent r_L in sector 1.
- Sector 2 (export sector):
  - We substitute K in the FOC for L.
  - Given that $\theta = \infty$, $p_2{=}\bar{p}_2$, hence the optimal levels of K_2 and L_2 correpond to the price on the international market.
  - From the corresponding amount of L_2, we can derive the land rent r_L in sector 2.
- By equalizing both of these land rents, we can analyze the effect of the policy mix in equilibrium on the amount of land that is demanded in both sectors (L_1 and L_2), the land price (r_L), the level of capital investment (K_2) and production (Y_2), and the effect on food prices (p_1).

The case of competitive land markets (detailed proof)

- From (5) and (6) we obtain $\frac{K_1}{L_1} = \frac{\beta_1}{\gamma_1}\frac{r_L}{r_K}$. Using (13) and the production function we have that $1 = G^{\alpha_1} K_1^{\beta_1} L_1^{\gamma_1}$. Combining these two expressions and solving for r_L we obtain

$$G^{-\frac{\alpha_1}{\beta_1}} L_1^{-\frac{1}{\beta_1}} \frac{\gamma_1}{\beta_1} r_K = r_L \tag{16}$$

The case of competitive land markets (detailed proof)

- Solving (5) for K_2, inserting into (6) and using (14) we have

$$\gamma_2 \left(\left(\frac{\beta_2}{r_K} \right)^{\beta_2} (1-\tau)\bar{p}_2 G^{\alpha_2} \right)^{\frac{1}{1-\beta_2}} = r_L. \tag{17}$$

- Combining (15) and (16) and solving for L_1 we obtain

$$L_1 = \left(\frac{\gamma_1}{\gamma_2 \beta_1} \right)^{\beta_1} G^{-\frac{\alpha_1\gamma_2+\alpha_2\beta_1}{\gamma_2}} r_K^{\frac{\beta_1}{\gamma_2}} \beta_2^{-\frac{\beta_1\beta_2}{\gamma_2}} ((1-\tau)\bar{p}_2)^{-\frac{\beta_1}{\gamma_2}} . \tag{18}$$

- From this expression we obtain $\frac{dL_1}{d\tau} > 0$ and $\frac{dL_1}{dG} < 0$. Using (17) we obtain $\frac{dr_L}{d\tau} < 0$ and $\frac{dr_L}{dG} > 0$.
- Combining (1) and (12) we have $\frac{dL_2}{d\tau} = \varepsilon r_L^{\varepsilon-1} \frac{dr_L}{d\tau} - \frac{dL_1}{d\tau} < 0$ and $\frac{dL_2}{dG} > 0$.

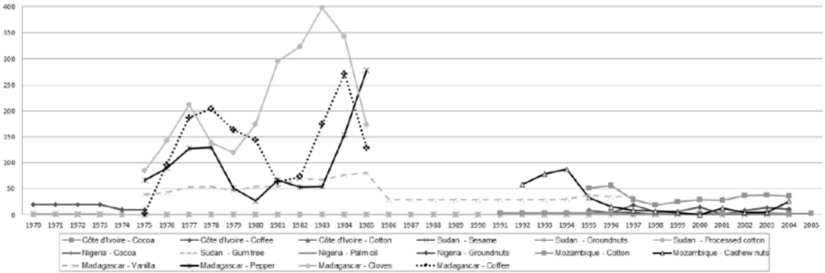
Effect of the policy mix on production and capital use in the exporting sector (detailed proof)

- Furthermore, solving (5) for K_2 and plugging L_2 into the equation, we obtain $\frac{dK_2}{d\tau} < 0$ and $\frac{dK_2}{dG} > 0$.
- Using the production function we have $\frac{dY_2}{d\tau} < 0$ and $\frac{dY_2}{dG} > 0$.
- Using (2) we can observe that deforestation decreases with a tariff increase and increases with an increase in public investment.

The effect of the policy on food prices depends on the relative size of the output elasticity of public investments in the two sectors (detailed proof).

- Using the capital-labor ratio in sector 1 we have $K_1 = \frac{\beta_1}{\gamma_1}\frac{r_L}{r_K}L_1$.
- Since we assumed that firms produce with constant returns to scale, they make zero profits.
- Therefore, $p_1 = (r_K K_1 + r_L L_1) = (r_K \frac{\beta_1}{\gamma_1}\frac{r_L}{r_K}L_1 + r_L L_1) =$ $\frac{r_K}{\beta_1} G^{-\frac{\alpha_1}{\beta_1}} L_1^{-\frac{\gamma_1}{\beta_1}} = r_K^{\frac{\gamma_2-\gamma_1}{\gamma_2}} \beta_1^{\beta_1} G^{\frac{-\alpha_1\gamma_2+\alpha_2\gamma_1}{\gamma_2}} \left(\frac{\gamma_2}{\gamma_1}\right)^{\gamma_1} \beta_2^{\frac{\beta_2\gamma_1}{\gamma_2}} ((1-\tau)\bar{p}_2)^{\frac{\gamma_1}{\gamma_2}}$.
  With this we have $\frac{dp_1}{d\tau} < 0$ and $\frac{dp_1}{dG} < 0 \Leftrightarrow \frac{\alpha_2}{\gamma_2} < \frac{\alpha_1}{\gamma_1}$. □

Historical export tariff levels



Appendix VI

Financing institutional and fiscal policies in the REDD+ context

- Carbon markets do not yet provide considerable amounts of funding for forest carbon offsets.
- Beyond public funding it is unclear how REDD+ is going to be financed in the future. A variety of funding sources are currently envisioned (decision 2/CP.17., paragraph 65 UNFCCC,2011b)
- Markets: The main emission trading schemes have so far been reluctant to include REDD+ credits.
- The current approach to REDD+ in the international negotiations follows very much a bottom-up logic, which creates path dependencies for the implementing countries, but does not take potential future restrictions to REDD+ credit inclusion by ETS into account.
- Jurisdictional REDD+ offers the opportunity to implement more systematic emission reductions.

Ideas for jurisdictional REDD+ market linkage

- Market linkage could increase the amount of private funding for countries that have already built up the necessary institutions for REDD+
- It could allow to direct public funding to countries that are still in the process of setting up national institutions for REDD+
- REDD+ market linkage could be institutionally faciliated
  - Trading ratios
  - Long term liability contracts
  - Jurisdictional REDD+ risk disclosure and rating
  - Minimum price for offsets (Koch et al., 2017)