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Analysis

Governance and deforestation — a meta-analysis in economics

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ABSTRACT

Understanding which aspects of forest governance have the potential to effectively reduce deforestation is central to reversing trends in global deforestation. There is a multitude of empirical studies examining this relationship using various measures of governance and study designs, coming to diverse conclusions. In order to identify the source of variation across studies, this article conducts a meta-analysis of 32 empirical cross-country studies in the field of economics, containing 227 estimates of the impact of different governance measures on deforestation. Using an ordered probit model, we find that the choice of the governance measure is the main factor in explaining variations in the outcomes of the studies. In particular, studies using environmental policy, ownership rights, presence of environmental NGOs, and rule of law as measures of governance, are more likely to find that better governance reduces deforestation. In contrast, studies using democracy and rights as a measure of governance are more likely to find that deforestation increases, when governance is improved. The finding that not all aspects of governance improvements are equally supportive of forest conservation suggests that more nuanced analyses of specific aspects of environmental governance are required to guide evidence-based policy making.

1. Introduction

In an effort to reduce emissions from deforestation, growing attention is being paid to the role of political institutions in national forest conservation strategies: out of 70 countries planning to roll out national REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programs, 54 explicitly state in their national REDD+ documents that governance issues are a concern for forest conservation, or that they want to address such issues in order to reduce deforestation (UN-REDD, 2016; FCPF, 2016).

There is a rapidly growing empirical literature examining deforestation drivers (Busch and Ferretti-Gallon, 2017; Choumert et al., 2013) and the effect of the quality of governance on deforestation (Deacon, 1994; Bhattarai and Hammig, 2001; Arvin and Lew, 2011; Ehrhardt-Martinez et al., 2002). Studies in the latter strand of the literature come to fundamentally diverging conclusions on the central question whether better governance leads to a reduction in deforestation, hereafter referred to as the governance hypothesis. While a number of studies support the hypothesis, others yield inconclusive results, or reject it.

Taking stock of the literature is hampered by substantial heterogeneity in terms of study design. Most notably, a broad spectrum of governance measures is used to operationalize the quality of governance. These various governance measures can reflect very different components of political institutions. Learning from previous studies is further complicated by significant variations in the methodology employed. Indeed, studies that use the very same governance measure in some cases still come to contradicting conclusions, which suggests that other study design choices, such as the estimation technique, also influence the results. For example, while Li and Reuveny (2006) or Buitenzorgy and Mol (2011) find that more democracy is likely to reduce deforestation, Midlarsky (1998), Marquart-Pyatt (2004), and Ehrhardt-Martinez (1998) find that it can actually increase deforestation.

In this study, we conduct a meta-analysis of the literature in the field of economics to provide a systematic analysis of the relationship between deforestation and the quality of governance. The analysis is based on a sample of 227 estimates originating from 32 studies conducted between 1994 and 2016. We classify the estimates by direction and statistical significance and use an ordered probit to draw systematic comparisons across studies. The analysis provides a quantitative insight into which factors explain the variation in the multitude of study outcomes. In particular, we seek to identify which aspects (general or specific environmental) and levels (decision process, rules, or enforcement) of governance tend to have a robust deforestation-reducing effect across different study designs. Theory guides us in hypothesizing that

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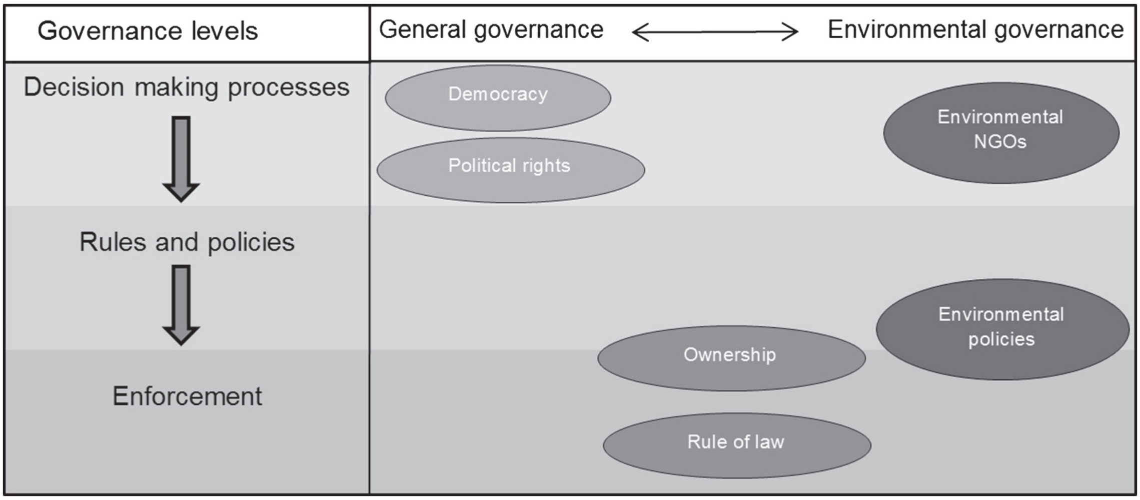

Fig. 1. Two-dimensional framework of governance.

studies using an environmental governance measure (e.g. environmental expenditures) are more likely to be supportive of the governance hypothesis than those using a general governance measure (such as liberal democratic institutions). Furthermore, emphasis is placed on the role of control variables, model specification and estimation technique, as well as the spatial context and study period.

In contrast to a literature review, a meta-analysis is a systematic analysis of empirical research using objective criteria for the selection of literature and statistical tools for the identification of systematic patterns across studies that can be reproduced (Waldorf and Byun, 2005; Stanley and Doucouliagos, 2012). Existing meta-studies in the field allow conclusions to be drawn on the current scientific consensus on (i) deforestation and land tenure rights security (better land tenure rights are likely to reduce deforestation, Robinson et al., 2014), (ii) deforestation and income (more recent publications find less evidence for the hypothesis that higher income countries are likely to experience less deforestation, Choumert et al., 2013) or (iii) forest restoration (a meta-analysis reveals that forest restoration bears the potential to significantly enhance biodiversity, Crouzeilles et al., 2016). Furthermore, Busch and Ferretti-Gallon (2017), Angelsen and Kaimowitz (1999), as well as Lambin et al. (2001) provide reviews of the literature on drivers of deforestation, without identifying and quantifying systematic patterns. There is, to the best of our knowledge to date, no meta-analysis examining the relationship between governance and deforestation.

The remainder of this paper is organized as follows. We will first present the conceptual framework for the analysis in Section 2. In Section 3, we present the data selection strategy, describe the main moderator variables and provide descriptive statistics for our analysis. In Section 4 we present the meta-analytical model. In Section 5 we report the results and Section 6 concludes with a broader discussion.

2. Conceptual Framework

Guided by the conceptual literature, we present a simple framework in this section that decomposes two basic dimensions of governance, which lead to two more refined versions of the general governance hypothesis and indicate possible different underlying mechanisms (Ferraro and Hanauer, 2014; Meyfroidt, 2016).

As a vertical dimension, we distinguish between different levels of governance. We build upon the forest governance framework proposed by the FAO and PROFOR (2011) and differentiate between the three levels: (i) decision making processes, (ii) rules and policies, and (iii) enforcement. These three levels can be conceived as following a (vertical) ordering, because decision making processes (processes that are required to change the status quo, Tsebelis, 1995), produce rules, (*de jure* dimension of governance, Kaufmann et al., 2007) that are subsequently enforced (*de facto* dimension of governance, Kaufmann et al., 2007). Of course, weaknesses in the enforcement of existing rules can also trigger new decision making processes. However, we can assume that no new rules are going to be enforced without having been subject to decision making processes beforehand. We hypothesize that the use of governance measures at different levels can partly explain the inconclusive findings on the governance hypothesis across studies. We refer to this refinement as the vertical dimensions of the governance hypothesis. If good governance at a specific level was more likely to reduce deforestation, this would also allow more focused policy advice on reforming political institutions.

As a horizontal dimension, we follow Ceddia et al. (2014) and differentiate general from specific environmental measures of governance. Ceddia et al. (2014) argue that better general governance (e.g. liberal democratic institutions) is likely to increase the demand for agricultural land and thus implicitly leads to more deforestation. Such a Jevons effect (Jevons, 1866) occurs, when efficiency increases (here induced by governance improvements) for an input factor to production (here agricultural land) allow to increase output levels of production. On the other hand, specific measures of the quality of environmental governance (e.g. environmental expenditures) are predicted to reduce demand for land as an input to agricultural production. This is referred to as a landsparing Borlaug effect. A Borlaug effect (Borlaug, 2007) occurs when efficiency improvements lead to a reduced use of natural resource based input factors to production. Along these lines, we hypothesize that studies using an environmental governance (general governance) measure are more (less) likely to be supportive of the governance hypothesis. We refer to this refinement as the horizontal dimensions of the governance hypothesis.

Fig. 1 illustrates the two dimensions of governance described above that will guide the subsequent analysis. It depicts the vertical and horizontal refinement of the general governance hypothesis. For illustrative purposes, we display the six governance variables that we identify in the meta-study sample as the most frequently used governance variables (details follow in Section 3).

3. Data

3.1. Data Selection

We follow the data selection standards for meta-studies proposed by Stanley et al. (2013). We impose four study selection criteria. First, we decide to restrict the scope to peer-reviewed articles and academic working papers and exclude all other types of publications. Second, we restrict our selection to the disciplines of economics, econometrics, and finance (see Appendix A for details). Third, we only include studies that cover at least three different countries, in order to make sure that results are not simply valid for a very specific (e.g. national) context. Finally, we restrict the search to papers written in English.

To build an initial study sample, we draw upon the review paper by Angelsen and Kaimowitz (1999) and the meta-analysis by Choumert et al. (2013).[1] 77 of the articles in Choumert's et al. meta-analysis and 27 articles from Angelsen and Kaimowitz's review are considered relevant according to our criteria and selected for the analysis based on their title. As a next step, we develop a keyword combination for a systematic search for publications. We test different types of boolean connectors and eventually use the keyword combination "deforestation AND (governance OR institutions) AND (regression OR empirical)" for our search. We use a simplified version of the keyword combination if the actual combination is technically not possible in a search portal (see Appendix A for the precise combination and search criteria for each platform, given its technical restrictions). We then conduct a keyword search using ScienceDirect, Wiley, JSTOR, Springer, SAGE, and Taylor and Francis for peer reviewed publications, and EconPapers (REPEC) and SSRN for working papers. We extract the results corresponding to our search criteria for EconPapers, ScienceDirect, Wiley, JSTOR, Springer, and SSRN on the 21st of February 2016 and for SAGE Publications and Taylor and Francis on the 29th of February 2016.

In total, across all different search portals, the keyword search yields 1740 results. Adding the 104 publications from the initial study population, we have a total of 1844 publications.

We then assess whether the 1844 articles correspond to the purpose of our meta-analysis based on their abstracts. We exclude (i) 392 publications that use non-empirical methods, (ii) 713 with local or national scope (we are only interested in cross-country assessments), (iii) 29 duplicates, (iv) 670 studies that are concerned with a different topic, (v) 5 non-English studies, and (vi) 3 studies with contradictory results. The final sample comprises 32 studies.

These 32 studies contain a total of 277 estimations of the impact of governance on deforestation. We cannot take estimates into account that include various governance variables indicating different directions of causality (and thus a contradictory link). We therefore have to exclude 50 observations. The sample is thus further constrained to 227 observations for our analysis. While the key word and criteria driven sample selection ensures replicability, the procedure also implies that we meta-analyze only a well-defined sample of the literature and not the entire population of the literature on the topic of governance and deforestation.

Appendix A indicates how many studies are attributable to the respective search portals (in the first search and in the final sample). All coding steps are verified by three independent coders. Spot checks were undertaken by two further coders.[2] The codebook (coding instructions) and the coded information (coding form and data) are available upon request.

3.2. Descriptive Statistics and Exploratory Analysis

3.2.1. General Information on the Sample

Table 1 summarizes the 32 studies included in the analysis and the respective number of estimates. We include only empirical studies that examine the effect of governance on deforestation across countries. All studies were published between 1994 and 2015. The total study population contains three working papers, corresponding to 60 estimates, and 29 articles published in academic journals, corresponding to 167 estimates. The average impact factor (SCImago Journal Rank) of the sample journal articles is 1.33 (min. 0.31; max. 8.05). The average number of citations (Google Scholar) of all sample studies amounts to almost 59 (min. 1; max. 380).

Table 1
Studies included in 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

3.2.2. Definition of the Effect Categories

The empirical studies in our sample use very different econometric modeling strategies and variables, making it extremely difficult to define a common, scale-free metric of estimated effect sizes for the impact of governance on deforestation. This broad variation allows us to only meta-analyze the direction and statistical significance of the effects rather than their magnitude. By using a simple classification of sign and significance (rather than pooling inconsistent actual effect sizes), we can exploit the full sample of study results and still focus on the main issue of whether a link between governance and deforestation exists. We interpret the results with respect to the widespread hypothesis (Geist and Lambin, 2002; Culas, 2007; Mendelsohn, 1994) that better governance leads to a decrease in deforestation. Following this logic, the reported results are categorized as 'positive' (supportive of the governance hypothesis) if an increase in the quality of governance leads to a statistically significant decrease in deforestation, 'inconclusive' if no statistically significant relationship can be established, and 'negative' (non-supportive of the governance hypothesis) if an increase in institutional quality leads to a statistically significant decrease in forest cover. Better governance is defined differently from one study to the other. The respective governance variables can use ordinal (e.g democracy), or cardinal (e.g. amount of environmental NGOs in the country) units. In addition, they can be scaled differently: a high score can correspond to better governance in one study, while it corresponds to worse governance in the other. The three effect categories allow to consistently classify effects across studies in spite of study specific differences.

[1] Both publications have a disciplinary background in economics. The review paper has a focus on economic models and the article is published in an economic journal.

[2] All coding steps were undertaken by Sebastian Lübbers, Annika Marxen, and Johanna Wehkamp. Spot checks were undertaken by Nicolas Koch and Sabine Fuss.

Table 2
Definition of variables and summary 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	Nonlinear 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

We use a 10% critical significance level for the categorization.[3] Out of the 227 observations, 22 are negative, finding evidence against the governance hypothesis, 82 do not find statistically significant results, and 123 support the governance hypothesis (see Table 2).

3.2.3. Moderator Variables

Moderator variables are used to capture different features and specifications of the estimates that influence the outcome. We group the moderator variables into five moderator variable categories: (i) governance measures, (ii) control variables, (iii) spatial, (iv) temporal, and (v) econometric specifications.[4] Including the moderator variables allows us to investigate the extent to which different governance or control variables as well as different spatial, temporal and econometric specifications, systematically influence the direction and significance of the observed effect.

Table 2 lists each moderator variable, its abbreviation, definition, mean, standard deviation, as well as minimum and maximum values.

We subsequently provide a short description and explanatory analysis of each category of moderator variable. We use a two-proportion z-test in order to understand whether the proportion of studies finding positive, negative, or inconclusive results is significantly different when a particular moderator variable is used. Table 4 displays the results of the test for each category.

Governance Variables: We include the following six governance measures in the moderator variable category 'governance': (i) *environmental_policy*, (ii) *ownership*, (iii) *democracy*, (iv) *NGOs*, (v) *rights*, and (vi) *rule_of_law*. We select these six governance measures from a set of 13 governance measures initially identified in the sample with very minor forms of aggregation (listed in Table 3).

More specifically, we cluster environmental policy, international environmental policy, and environmental compliance (which is a composite indicator constructed with the variables corporate ethics, burden of government regulation, and stringency of environmental regulation) into the category *environmental_policy*. The variable *environmental_policy* can be defined as measuring in how far the national policy framework internalizes environmental concerns. Due to the fact that international environmental policy measures have to be endorsed by national governments, they can be considered as being part of domestic environmental policies. Furthermore, given the way the variable environmental compliance is constructed, it indirectly also measures environmental policy. The different studies use data from Dietz and Kalof (1992), data from the WTO's government finance statistics (2016), the Center for International Earth Science Information Network (CIESIN, 1990), the World Resources Institute's guide to the global environment (1998), the Global Competitiveness Report (Schwab and Porter, 2009), or the World Economic Forum's WEF (2012) indicator on corporate ethics, and on the stringency of environmental regulations.

The moderator variable *ownership* measures the probability of expropriation and the protection of property rights by a political system. The underlying studies use data from Banks and Wilson (2017) cross national time series data archive, the International Country Risk Guide (2015), Fraser Institute (2016), or data from Acemoglu et al. (2001).

The variable *democracy* measures the extent to which a country has liberal democratic institutions (separation of powers) and processes.

Table 3
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

[3] We also experiment with a 5% critical significance level. However, this lower threshold reduces the sample size (particularly, of the category 'negative') to an extent that prevents us from conducting a meaningful meta-regression analysis.

[4] We also experiment with the type of forest data that is used in the sample studies. However, this potential additional moderator does not seem to explain the variation in study outcomes.

Table 4
Binary moderators 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*
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*
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

* Z-value that is larger than 1.64.

The respective studies use data from Marshall and Jaggers Polity Index (2002), Bollen's Political Regime Index (1993), or from Banks and Wilson's (2017) Cross-National Time-Series Data Archive.

The moderator variable *NGOs* measures the presence of environmental NGOs in a country. The respective data come from the yearbook of international associations as compiled by Smith and Wiest (2005), Smith (2015), the Center for International Earth Science Information Network (Shandra, 2007b), or Dietz and Kalof (1992).

The moderator variable *rights* represents political rights and civil liberties. Studies use data provided either by Freedom House (2009), or by Kaufmann et al. (1999). The variables grouped in this category have different subcomponents, but all focus on the quality of the political process. Subcomponents are for instance the electoral process, political pluralism, the right to associate, as well as the protection of individual rights.

We group the categories rule of law and enforcement into the category *rule_of_ law*, because they are used interchangeably in the literature. The variable can be defined according to the World Bank (2014) definition, as capturing "*perceptions of the extent to which agents have confidence in and abide by the rules of a society*". The corresponding World Bank dataset (World Governance Indicators) has been used for the majority of estimates (22 out of 36). Other sources are the International Country Risk Guide (2015) and the Fraser Institute (2016).

There are less than 20 observations (a common threshold in meta-analysis) in the initially identified categories of quality of the administration, corruption, inequality, and stability. These categories are therefore not included as distinctive moderator variables.

Table 4 provides us with a first insight into whether the proportion of findings changes significantly when different governance variables are used in the analysis.[5] Indeed, the bivariate analyses suggest that the choice of the governance variable can have a meaningful impact on study outcomes as reflected by significant variations in the proportions of positive, negative, and inconclusive results. While the effect on the study outcome of using *environmental_policy* and *ownership* as governance measures is either weak or non-existent, the use of the other governance variables seems to make a significant difference to the respective outcome proportions. In particular, studies that use *democracy* and *rights* show a significantly lower proportion of positive estimates, while the proportion of negative estimates is significantly higher. The variables *NGOs* and *rule_of_law* have the contrary effect; for both these variables we can observe a significant increase in the proportion of positive findings and a significant decrease in the proportion of negative findings.

Control Variables: Five control variables are selected as additional moderator variables: (i) *population* (including population density and population growth rate), (ii) *income* (including different measures of income such as GDP, GNI, GNP etc.), (iii) *area* (including different measures of the forest area), (iv) *timber* (including different measures of timber harvest), and (v) *agriculture* (including agricultural yields, agricultural production, agricultural exports etc.). The respective control variables are selected as moderator variables, because they are most frequently used in the regressions of our study population. There are intensive discussions in the literature, especially related to the variables: (i) *population* (whether more population density and growth increases (Mather and Needle, 2000; DeFries et al., 2010) or decreases (Pfaff, 1999) deforestation) and (ii) *income* (whether income growth leads to less or more deforestation Choumert et al., 2013). Moreover, existing reviews find that *agriculture* is the main direct driver of deforestation worldwide (Angelsen and Kaimowitz, 1999; Rudel et al., 2009).

Table 4 shows that two variables seem to significantly impact the outcome proportions. First of all, including the variable *timber* significantly reduces the proportion of positive outcomes and increases the proportion of inconclusive ones. Second, including the variable *agriculture* significantly increases the proportion of positive and reduces the proportion of negative outcomes. The other control moderator variables (*population*, *income*, and *area*) do not have a significant impact on the outcome proportions.

Spatial Variable: The only spatial moderator variable that is consistently identified across studies is the variable *developing_countries*. It allows to account for whether a study includes high income countries (according to the World Bank (2016) income classification of the year of publication) or not. All studies that exclude high income countries

[5] Baseline proportions: positive 54.19% (123 obs.); insignificant 36.12% (82 obs.); negative 9.69% (22 obs.)

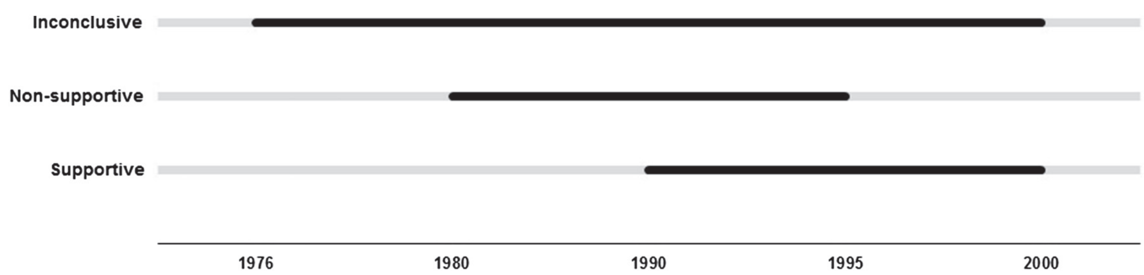

Fig. 2. Median start and end years of studies in sample.

are categorized as developing countries studies. Studies that do not list the countries included in their sample, but state that only developing countries have been used for the analysis, are also included in the category *developing_countries*. Table 4 shows that studies that exclusively rely on *developing_countries* have a statistically significant lower proportion of positive findings.

Temporal Variables: To account for the potential influence of the temporal context, we include the variable *period* into the regression model, which records the average year (rather than both the start and end year) of the sample period. Given the differences in length of the study periods, we also include the square root of the sample size through the variable *size* and use this variable for robustness tests. Fig. 2 shows the median of the start and end years of the time periods used for the estimations in the sample. It reveals that positive results are on average associated with later periods (1990–2000) than negative results (1980–1995). Studies with inconclusive results are on average based on longer time periods.

Econometric Variables: The first moderator variable in this category relates to data characteristics. The dummy variable *panel* distinguishes panel data settings from cross-sectional settings. Given that the fixed effects of panel data models can control for time-invariant unobservable differences between countries or regions, the research design of studies based on panel data is considered to be more robust than that of cross-sectional studies. Table 4 shows that using panel data significantly lowers the proportion of positive effects and increases the occurrence of insignificant findings. Furthermore, the dummy variables *dynamic* and *nonlinear* code studies that build on dynamic regression specifications (e.g. lags in levels and/or changes) and nonlinear specifications (e.g. quadratic and/or interaction terms) of the relationship between deforestation and governance, respectively. While the bivariate test suggests that particularly dynamic models are more likely to yield insignificant effects and less likely to yield positive effects, there are no significant differences in the distribution of the effect category when nonlinearities are accounted for. Finally, 56% of the estimates are based on OLS estimation.[6] The results for the corresponding bivariate *OLS* variable indicates that an OLS estimation is more likely to produce positive effects and less likely to produce insignificant effects, compared to more sophisticated estimation techniques. This observation is in line with expectations given the typically low standard errors of OLS.

Publication Bias Variable: A publication bias could be present in the analysis if there was a tendency to publish a certain type of outcome in peer-reviewed journals. Several methods are available to detect and correct for potential publication biases in settings with continuous effect size estimates (e.g. Hedges, 1992; Stanley, 2008). However, these techniques cannot be applied in our categorical model design. We therefore seek to mitigate potential biases by controlling for the type of publication. More specifically, the dummy variable *type* distinguishes published journal articles from working papers. The exploratory bivariate analysis in Table 4 suggests that peer reviewed articles may have a significantly larger proportion of negative findings. In the subsequent analyses, we also include the publication *year* to avoid any biases from time trends in the published literature.

[6] Other estimators used include for instance GMM, logit, probit, fixed, and random effect specifications

4. Model

The preceding exploratory analysis points to a number of moderator variables that may significantly contribute to the observed variations in the findings across our study universe. However, the bivariate z-test neglects the potential simultaneous influence of various other variables and thus, may suggest relationships that do not exist. Therefore, we turn to a multivariate meta-analysis to properly identify the salient sources of variations in terms of direction and significance. Given that the three effect categories have a natural ordering by the t-statistic, an ordered probit model is appropriate for our modeling purposes. This is also the approach taken in Waldorf and Byun (2005) and Card et al. (2010).

We denote the three observed effect categories as y, taking the values 0, 1, or 2 when the estimated effect is negative, inconclusive, or positive, respectively. The observation y is assumed to be related to the latent continuous variable y^*, which denotes the exact but unobserved estimated effect size derived in each analysis. y^* is assumed to be a linear combination of some measurable moderator variables x, i.e. $y^* = x\beta + \varepsilon$, with ε being the disturbance term that has a standard normal distribution. More specifically, the link between y and y^* can be defined as follows (Greene, 2012)

$$\begin{aligned} y = 0 \;\; &if \;\; y^* \le 0 \\ y = 1 \;\; &if \;\; 0 < y^* \le \mu_1 \\ y = 2 \;\; &if \;\; \mu_2 \le y^*. \end{aligned} \tag{1}$$

Having established the link between y and y^*, we are also interested in estimating how a change in a moderator x translates into the probability of observing a particular effect category j. It is given by

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

where Φ is the standard normal distribution function, and $\Phi\ (\mu_0 - x\beta) \equiv 0$ and $\Phi\ (\mu_2 - x\beta) \equiv 1$.

The coefficients β and the thresholds μ in the ordered probit model can be estimated straightforwardly by maximum likelihood. Note that a positive β coefficient suggests a positive effect of the moderator variable x on the probability of finding a positive result (i.e. $P(y = 2)$) and a negative effect on the probability of a negative result (i.e. $P(y = 0)$). Even though the coefficient estimates can be interpreted based on their significance and signs, they do not reveal the magnitude of changes in the probability of observing each effect category in response to changes in x (precisely because the model is nonlinear). To this end, we present the corresponding marginal effects. We use the pseudo-R^2 of McFadden (1974) as a measure of fit of the model.

Two data characteristics of our sample require particular attention and we tailor our estimation techniques to these features (see Nelson and Kennedy, 2009 for an excellent discussion of the often neglected specificities of the data-generating process in meta-regression analyses). First, we have multiple effect estimates from the same primary study (see Table 1), i.e. there is potential within-study correlation. To deal with this common problem in the meta-regression literature, we use robust standard errors that are clustered by study (Nelson and Kennedy, 2009). Second, the sample sizes clearly vary across the effect estimates in our sample (see Table 2). This raises the concern that there may be a 'mechanical' effect of the sample size on the distribution of *t*-statistics (and thereby on our dependent variable), i.e. bigger study samples are more likely to deliver significant *t*-statistics (Card et al., 2010). Our strategy to account for this concern is two-fold. On the one hand, we present estimation results that are based on weighted observations. More specifically, we use (the logarithm of the square root of) the sample size as a weight, which is a common method to correct for robustness differences in the literature (Waldorf and Byun, 2005; Brons et al., 2008; Nelson and Kennedy, 2009).[7] On the other hand, we conduct further specification tests to evaluate the validity of our analysis, which in fact will show that the mechanical effect of the sample size seems to be mitigated by other design factors.

5. Results

Table 5 reports the estimation results of the ordered probit model. The first numerical column shows the coefficient estimates. The last three columns show the marginal effects for each effect category (negative, inconclusive, and positive).

In a nutshell, three main findings emerge. First, none of the different governance levels (processes, rules, and enforcement) homogenously increases the likelihood of a certain study outcome. Second, studies using specific environmental dimensions of governance are more likely to find results that are supportive of the governance hypothesis. Third, the choice of control variables as well as the estimation technique can significantly influence the study outcome. We subsequently present and discuss these results in more detail.

5.1. Influence of the Choice of the Governance Measure

The results in Table 5 show that the choice of the governance measure is the primary source of variation in the sign and significance of effect estimates. This holds true both for the significance of the coefficients and the magnitude of marginal effects. While the variables *environmental_policy*, *ownership*, *NGOs*, and *rule_of_law* increase the likelihood of positive findings, using the variables *democracy* and *rights* has the contrary effect.

5.1.1. Decision Making Processes

The variables *NGOs* and *democracy* measure the quality of decision making processes. The meta-analysis shows that studies are more likely to find that better governance increases deforestation, when the general governance measure *democracy* or *rights* are used. In contrast, we find that studies using the presence of environmental *NGOs* as an specific environmental governance variable are more likely to find that deforestation decreases.

More specifically, when governance is operationalized by *democracy*, the likelihood of a positive outcome is reduced by 38% (at a 5% significance level). Furthermore, the marginal effects suggest that using this variable increases the probability of inconclusive findings by 23% (at a 1% significance level). Similarly, using the variable *rights* reduces the likelihood of a supportive outcome. The strong marginal effects of the *rights* variable are particularly noteworthy. They suggest that the probability for positive findings is reduced by 53%. At the same time, using rights as a governance measure increases the likelihood of finding an insignificant or negative result by 29% or 25%, respectively. In contrast, the marginal effects for the governance measure *NGOs* indicate that using this variable increases the likelihood of positive results by 52%, while the probability of finding inconclusive (negative) results decreases by 47% (5%).

The presented results reflect both the role of the openness of the political process to civil society participation and the specific role of environmental awareness. The example of Brazil illustrates the channel through which civil society lobbying for environmental policy can turn forest conservation into a political priority: set under pressure by civil society organizations, a range of large-scale agricultural corporations agreed to the soy moratorium (Gibbs et al., 2015). This situation fostered further political action to reduce deforestation (Nepstad et al., 2014). Our analysis indicates that using more disaggregated data and conducting a more refined analysis on a specific aspect of a policy process, the role of the environmental civil society, rather than the degree of democracy in general, generates drastically different and more nuanced conclusions. This also allows more practical insights into which policies allow the systematic reduction of deforestation.

Table 5
Results ordered probit model.

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)			
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)			
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-R^2	0.2522			

Standard errors (clustered by study) in parentheses.
Estimated cutpoints are not reported.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

[7] Ideally, we would use the inverse of the variance as weights. However, the variances are only reported in a small sub-sample of our primary studies.

In particular, the results on the governance measure *democracy* and *rights* suggest that deliberative political processes do not necessarily lead to environmentally sustainable outcomes. If *democracy* in fact measures, whether a country has democratic decision making processes, then the results show that more opportunities for democratic participation are not necessarily used to express environmental concerns. This reflects the contradiction in the literature on the role of democracy for forest conservation; while Didia (1997), as well as Li and Reuveny (2006) find a positive impact of more democracy on forest covers, Midlarsky (1998), Ehrhardt-Martinez (1998) and Marquart-Pyatt (2004) find that more democracy leads to more deforestation. Buitenzorgy and Mol (2011) reconcile the opposing views by describing an inverted U-shaped curve, representing the transition. However, in their linear model specification, an increase in democracy also leads to an increase in deforestation. Arvin and Lew (2011) reconcile the opposing views by arguing that democracy reduces deforestation only in certain regions, while it increases deforestation in other regions. Kuusela and Amacher (2016) also point to the importance of political instability and the newness of a democratic regime in explaining why deforestation might increase in phases of democratic transition.

The results show that while political processes are likely to strongly impact the deforestation process, more research on the effect of specific forms of public involvement would be useful to draw policy relevant conclusions.

5.1.2. Rules

The variables *ownership* (i.e. land rights and general ownership security), and *environmental_policy* can be understood as forming part of the second pillar 'Rules', even though both of these moderator variables also contain governance measures that could be attributable to the governance level 'Enforcement'.[8] Using the variable *ownership* in an estimate increases the likelihood to find supportive results. The findings for the specific environmental governance variable *environmental_policy* document that studies based on this particular governance measure are significantly more likely to deliver estimates that support the governance hypothesis. This highlights again the importance of differentiating between general and environmental governance variables.

It is noteworthy that this result is not in line with the simple bivariate analysis discussed above. For *environmental_policy*, the coefficient estimate is only marginally significant at the 10% level. However, the marginal effects corroborate the relevance of the positive relationship and they are statistically significant at the 5% level.

The results for the variable *rights* are comparable to the findings for the variable *democracy*. They imply that neither more democratic decision making processes, nor a better protection of political rights through the rules of a state, necessarily lead to civil society commitment to forest conservation. The findings for the variable *ownership* are in line with Robinson et al. (2014) meta-analysis of individual case studies (rather than cross-national studies) on land rights security. While the impact of better land rights security on deforestation has been extensively discussed in the literature (cf. Liscow, 2013; Brown and Pearce, 1994; Angelsen and Kaimowitz, 1999; Mendelsohn, 1994), our finding confirms the hypothesis that better land tenure security tends to decrease deforestation. The result strengthens the narrative that while under certain local circumstances, land tenure rights might have led to temporary increases in deforestation rates (Liscow, 2013), forest conservation is more likely to operate effectively if a functioning land rights system is in place that allows the correct delimitation and enforcement of forest conservation areas. The findings for the variable *environmental_policy* are in line with the prediction that countries that are more committed to international environmental policy agreements and better domestic environmental policies are likely to be associated with less deforestation. We find that this relationship is consistent across different studies and study designs.

5.1.3. Enforcement

The third governance level 'Enforcement' is analyzed with the variable *rule_of _law*. The results show that using this governance measure in a study significantly increases the likelihood to find results that are supportive of the governance hypothesis. In terms of magnitude, the likelihood of finding a positive result increases by 35% while the probability of inconclusive results decreases by 30% (at a 5% significance level).

The variable *rule_of_law* is a general measure of governance, but it arguably has specific implications for environmental policy making. We can therefore not clearly attribute it to being either a general, or a specific environmental governance variable. Our findings are consistent with the more recent literature, for example they are in line with Barbier and Tesfaw (2015) who find that high scores in rule of law increase the likelihood of reaching a tipping point in deforestation, whereas high scores in regulatory quality reduces the probability of reaching this point.

5.2. Influence of Other Study Design Choices

5.2.1. Control Variables

Overall, we can observe that the inclusion of different control variables does not impact the outcome to the same extent as the governance variables. Still, the choice of control variables does influence the study outcomes.

In contrast to the bivariate tests, the variables *agriculture* and *timber* are not significant in the multivariate estimation model. However, and again in contrast to the bivariate analysis, the coefficients for the variables *population* and *area* are statistically significant at the 10% and at the 1% level, respectively. Including the control variable *population* increases the likelihood of finding positive results, while the inclusion of the variable *area* reduces this likelihood. The marginal effects confirm these findings. Furthermore, they show that it is 39% more likely to find insignificant results when the variable *area* is included, and 23% less likely to find inconclusive results when the variable *population* is included.

The results show that if an estimate controls for demographic changes, it is more likely to find that better political institutions reduce deforestation. This relationship could suggest that political institutions are more important, when demographic pressures to convert agricultural land are high. While this interpretation is only tentative, we believe that the institutions-population-deforestation nexus deserves further investigation.

Furthermore, the results on the variable *area* underline the importance of examining deforestation drivers in relation to existing forests stocks. This finding is in line with the strand of literature arguing that the existing forest stock influences deforestation trends. In this context the forest scarcity path (Wolfersberger et al., 2015; Rudel et al., 2005) is discussed most prominently. It argues that a country only starts to control deforestation politically, if the relative share of forest land has become small and forest products are thus scarce.

5.2.2. Spatial, Temporal, and Econometric Variables

The spatial context of the sample studies evaluating the governance hypothesis does not seem to explain the variation between the estimated effects. More specifically, the dummy variable for the non-high income country group (*developing_countries*) remains statistically insignificant, i.e. studies that only focus on developing countries do not find different results.

Turning to the temporal context, the exploratory analysis suggests that more recent sample periods are more likely to yield positive results. In contrast, the multivariate results unambiguously suggest that

[8] Given the fact that for both of these variables *de facto* and *de jure* dimensions of governance are used conjointly, no clear attribution to one or the other category can be made.

the study period (here taken into account through the variable *period*) has no effect on the probability of the three effect categories. Similarly, the (square root of the) sample size (*size*) is not a significant moderator variable. The insignificant marginal effects are in line with sampling theory, showing that a larger sample size tends to decrease the probability of insignificant findings. We return to the sample size effect in the evaluation of the model below.

Examining the moderator variables that control for econometric issues, we find that the estimated coefficients associated with data characteristics — measured by the variable *panel*, as well as model specifications — measured by the variables *dynamics* and *nonlinear*, remain insignificant in the baseline model, suggesting that these technical choices are not a relevant source of variation between the estimated effects.

However, the key finding concerning the econometric issues is that the choice of the estimator is non-trivial. More specifically, the coefficient estimate and marginal effects show that using *OLS* estimation rather than more sophisticated estimators reduces the probability of obtaining positive results and significantly increases the probability of obtaining inconclusive results. This result contrasts with the exploratory analysis, where the proportion of positive findings is significantly larger when OLS models are taken into account. The finding could indicate a potential endogeneity bias in estimates of the effects of governance on deforestation. Measurement error in the governance variable seems a particular likely source of endogeneity bias. Indeed, if the independent variables are subject to measurement error, then the OLS coefficient estimates will be biased downwards (Wooldridge, 2002), which could explain our findings.[9]

Finally, and in contrast to the binary test, there is no clear indication of a publication bias in the results. When looking at the variable *date*, there is no support for a publication trend or turn-around in publication bias as the effect of the publication year remains both statistically and substantively trivial. There is also no clear indication of a publication bias in the sample when looking at the variable *type* (of publication). The estimated coefficient for published journal articles suggests that these studies are neither more nor less likely to show significant effects of governance on deforestation than working papers. We also recall that the sample size is not a significant moderator variable, but it should again be noted that these tests for publication biases are only indicative. Future research should apply more sophisticated methods to detect and correct for potential publication bias, but this would go beyond the scope of our objectives.

5.3. Robustness Checks

We perform several additional analyses to assess the robustness of our results and methodology. First, to account for concerns that there may be a 'mechanical' effect of the sample size on the distribution of *t*-statistics and our dependent variable, we reestimate our ordered probit model based on weighted observations, using the square root of the sample size (Appendix Table B, column 1) and the logarithm of the square root of the sample size as weights (Appendix Table B, column 2) (similar to Waldorf and Byun, 2005). The weighted regression results are generally consistent with the unweighted estimates reported in Table 5.[10]

Second, to further investigate the role of sample size differences, we implement a simple specification test proposed in Card et al. (2010). We estimate separate probit models for the likelihood of significantly positive (Appendix Table B, column 3) and significantly negative (Appendix Table B, column 4) effect estimates that include the square root of the sample size. If there was a mechanical effect, a larger sample size should lead to larger positive *t*-statistics *and* larger negative *t*-statistics, i.e. we should find in both probit models a significantly positive coefficient for the square root of the sample size (in contrast, in our ordered probit regression the two effects might offset each other). Both estimated coefficients of interest are relatively small and clearly statistically insignificant, suggesting that there is no relationship between the sample size and the probability of either a significantly positive or significantly negative t-statistic. This finding suggests that the mechanical effect of sample size is mitigated by other design factors. Under a valid ordered probit model specification we would also expect the coefficients of the probit model for a significantly positive effect to be quite close to the ordered probit coefficients in Table 5, while the coefficients from the probit model for a significantly negative effect should be close in magnitude but opposite in sign. For the concerning data, the estimated coefficients are not in perfect alignment with this prediction, but the predicted pattern seems qualitatively correct, particularly for the moderators that turned out to be highly significant.[11]

Finally, we check whether our results are influenced by the choice of the number of effect categories used. More specifically, we use four rather than three effect categories (Appendix Table B, column 5) by splitting the insignificant findings into insignificant positive and insignificant negative effect estimates. The inferences concerning the effects of the moderator variables are highly consistent with the main estimation, with the only notable difference being that the variable *population* turns out to be insignificant.

6. Discussion and Conclusion

Existing empirical evidence of the effect of governance on deforestation is based on a variety of different governance measures, as well as diverse study designs. As a result, the existing literature yields supportive, inconclusive, and non-supportive results for the hypothesis that better governance reduces deforestation (governance hypothesis).

In this paper, we have used a meta-regression analysis to provide a systematic synthesis of the literature in the field of economics on the effect of governance on deforestation. In particular, we have examined, whether (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), or (iii) other methodological study design elements, significantly influence the results.

We have found no evidence that a particular level of governance systematically favors a supportive or non-supportive study outcome. However, our findings have corroborated the hypothesis that studies using specific environmental dimensions of governance, namely *environmental_policy* and the presence of environmental *NGOs*, are more likely to find results that are supportive of the governance hypothesis. Furthermore, our meta-analysis has highlighted the role of other study design choices. While using the control variable *population* significantly increases the likelihood of a study to find a supportive result, using the control variable *area* significantly reduces it. Moreover, we have shown that the estimation technique significantly influences the likelihood of a study to find results that are supportive of the governance hypothesis. In particular, using an ordinary least squares estimation technique significantly lowers the probability to find supportive results.

While the insights of this meta-analysis offer a first systematic evaluation of different studies that analyze the effect of governance on deforestation, the following limitations need to be taken into account, when interpreting the results.

[9] Similarly, measurement error in the dependent deforestation variable would increase the variance of the error term, i.e. lead to inefficient coefficient estimates.

[10] Given that the square root of the sample size varies widely (min. 4.5; max. 58.7), using this variable for weighting may over-correct for robustness differences. We have, however, also experimented using it as weights. The results are materially the same and available upon request.

[11] Note that we cannot include the full set of moderator variables in the probit model for significantly negative estimates because some moderators predict the outcome perfectly.

First, the heterogeneity in scales (ordinal and cardinal) and units of the different governance and forest measures in our sample allows us to only meta-analyze the direction and statistical significance of effects rather than their magnitude. Thus, our meta-analysis does not reveal relevant information regarding the size of deforestation-reducing effects of different governance measures. As the literature is still growing, future meta-studies may eventually build on a more homogenous study sample and close this research gap.

Second, in contrast to a literature review, a meta-analysis examines a very specific phenomenon and thus has a more confined range (Waldorf and Byun, 2005). In the context of our study, the literature sample is restricted to the field of economics and economics related publications. Our choice reflects the trade-off in meta-analysis between the benefits of having a broad sample universe of studies from the literature and the significant costs involved in the coding and verification of the sample studies, following the standards in meta-analytical research laid out by Stanley et al. (2013). Notwithstanding, research expanding the scope to studies from other fields, such as environmental sciences, political sciences, and sociology is required to corroborate the here presented conclusions.

Finally, as discussions in the literature on the effect of governance on economic growth reveal, the effects of general governance measures, such as democracy, civil rights, and rule of law have to be interpreted cautiously due to potential measurement errors. In particular, Kaufmann and Kraay (2008) draw attention to measurement errors in governance variables and conclude that one should think of governance indicators as *"all providing imperfect signals of fundamentally unobservable concepts of governance"*. Devarajan (2008) argues that aggregated national governance indicators, do not account for local differences in governance, which can imply further fundamental measurement errors. Kurtz and Schrank (2007) furthermore argue that such general governance measures suffer from perceptual bias and adverse selection problems in the sampling process. Furthermore, according to Kishor and Belle (2004) general governance measures can capture a variety of phenomena and thus do not allow to measure the specific effects of forest sector governance on deforestation.

In spite of these limitations, our analysis provides avenues and insights for future research on the effect of governance on deforestation. We would like to use the remainder of this concluding section to discuss these insights.

First of all, while we find that a differentiation of the three governance levels does not conclusively explain the variation in study outcomes in our sample, more explicit analysis of whether these different governance levels are likely to have different effects on deforestation patterns seems valuable.

Second, our analysis indicates that contrary to the widespread assumption that all aspects of governance improvements are equally supportive to forest conservation, it is worthwhile to examine the effects of specific aspects of governance in the forest conservation context and to understand the underlying mechanisms. Based on the above described criticism of general governance measures, an alternative explanation to the positive effect of general democracy and civil rights improvements on deforestation could also be that the highly aggregated and ordinal governance measures may not constitute adequate proxies for governance. Yet, more research is required to draw robust conclusions.

Third, a better understanding of environmental governance seems necessary. The aggregation undertaken in the moderator variable environmental policy still proposes a very high level of aggregation of different dimensions of environmental policy. The study sample does not yet allow such a refinement, because it contains too few observations on individual dimensions of environmental policy. Future research may focus on providing a more nuanced analysis of environmental and forest sector governance and aim at collecting more specific data on environmental and forest sector governance. Currently, a central obstacle to the refinement of such analysis remains the availability of data. The State of the World's Forests Report in 2005 already highlighted that the lack of data on forest governance is a problem for evidence-based policy making in the field.

Most of the currently available data on forest governance is subject to various limitations: the available data focusing on specific elements of forest governance are reported in non-discrete units (mostly nominal or ordinal data, such as the presence or absence of a forest code (e.g. World Resources Institute,WRI, 2014, Global Witness for Peru,Transparency International, 2012). Existing attempts to provide data on specific aspects of forest governance also use heterogeneous reporting standards for different countries. Consequently, the results are not comparable in a quantitative analyses. In addition, most initiatives to date only provide data for a selected number of countries (UN-REDD PGA for instance, for Indonesia (UN-REDD, 2012), Vietnam (UN-REDD, 2013), Nigeria and Ecuador). Finally, most data are only available for short time periods. The absence of panel data prevents the use of more sophisticated estimation techniques, which may yield more robust results.

Forest governance data that have been added to the global Forest Resources Assessments conducted by the Food and Agriculture Organization of the United Nations (FAO) in 2005, 2010, and 2015 represent a notable exception. The global Forest Resources Assessments contains data on forest ownership and management rights, the designated functions of forests, forest management and legal status, employment in the forest sector, forest policy and legal framework, human resources within public forest institutions, forest education and research, forest revenue and public expenditure on forestry, and the status of ratification of international conventions and agreements. While this could become a promising data source for a more nuanced analysis of the effect of specific aspects of forest governance, to date only a few studies have used these sources (e.g. Galinato and Galinato, 2016; Barbier and Tesfaw, 2015; Whiteman et al., 2015).

In order to enable policy advice to be tailored to country specific contexts, future research should focus on providing and using such more specific and more precise data on different aspects of forest governance. Kishor and Rosenbaum (2003), as well as Tegegne et al. (2014) discuss useful indicators for an improved measurement of forest governance in the European Forest Law Enforcement, Governance and Trade policy context. Kishor and Rosenbaum (2003) suggest, for instance, to measure the percentage of concession awards involving bribery, the records of concessions voided after discovery of illegality, or a record for concession holders to disclose familial connections to the government, as alternative and more precise measures for forest sector governance. Tegegne et al. (2014), suggest measuring the occurrence of illegal activities (illegal deforestation), the effective adjunction in forest related offenses, or the amount of resolved public disputes. Cowling et al. (2006) and Kishor and Rosenbaum (2012) provide guidelines for the collection of forest governance data. In view of the global increase of freedom of information laws (Ackerman and Sandoval-Ballesteros, 2006), freedom of information requests could be a promising method to collect such data for future research.

Furthermore, there are many deforestation drivers that lay outside of the forest sector that might also be related to weak governance. Future research could also evaluate in how far governance in other sectors, does affect deforestation rates. Ideally, research could provide guidance that would allow policy efforts for governance improvement, for instance in the REDD+ context, to be concentrated towards areas of governance that are most likely to be effective levers for forest conservation and furthermore exhibit the highest potential to yield positive spill-overs for other policy goals.

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Appendix A. Details on the Identification of the Study Population

Table 6
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 and Industry, Environment and Sustainability	29.02.2016	156	3
Choumert et al. (2013)	–		29.02.2016	77	9
Angelsen and Kaimowitz, 1999.	–		29.02.2016	27	2

Appendix B. Robustness Tests

Table 7
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-R^2	0.2525	0.2447	0.3111	0.3597	0.2234

Standard errors (clustered by study) in parentheses.
Estimated cutpoints are not reported.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

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