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Democracy and deforestation: The role of spillover effects

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ABSTRACT

This paper is a replication and extension of Buitenzorgy and Mol (2011). We recreate the data and analyses from that paper on the impact of democracy on deforestation from 1990 through 2000 with great precision before extending the data set and analyses to include the period from 2000 through 2010. We find that the original results of Buitenzorgy and Mol (2011) were spurious and inconsistent in the replication once heteroskedasticity robust standard errors were employed. When combining the two time periods and running analyses on panel data and differenced data for robust outcomes and better policy inferences, we find different results for the effect of democracy on deforestation, indicating that model specification is critical to studying this relationship. The more econometrically sound method, the differenced models, reject the Environmental Kuznet's Curve (EKC) hypothesis for democracy and deforestation, instead indicating that democracy decreased deforestation rates. When adding democracy spillover effects to the model, i.e., the impact on deforestation rates due to changes in democracy levels in neighboring countries, we still find that democracy leads to decreased rates of deforestation. We also find that having more democratic neighbors leads to further decreases in democracy. These outcomes have far-reaching implications for the blocs examined, which are highlighted in this study.

1. Introduction

The relationship between democracy and deforestation has been at the heart of a heavily contested academic conversation for several decades in the related literature with no apparent consensus. There is much controversy as to whether or not democracy has any effect on deforestation and other environmental outcomes. For example, Scruggs (1998) found no significant impact of democracy on several environmental outcomes. Fittingly, those studies that do provide evidence that democracy impacts environmental outcomes often show polar opposite results. Midlarsky (1998) found that higher levels of democracy contributed to greater environmental degradation, while Shandra (2007b) found evidence that increased democracy leads to decreased rates of deforestation.

Arguments have been made that democracy leads to increased rates of deforestation since politicians are apt to allocate very little space in budgets to address deforestation and over allocate space in budgets for other economic concerns that their constituents have since this maximizes their chance at being reelected. Other authors have asserted that more authoritarian regimes can more easily enact environmental protection measures, assuming they value such measures (Neumayer, 2002). Conversely, arguments suggesting that democracy has a positive impact on environmental outcomes based on a strengthening of civil liberties and political involvement are plentiful (Didia, 1997; Shandra et al., 2012). Democracy is also associated with wealthier and more educated citizenries which might vote for stronger environmental protection measures (Rydning Gaarder and Vadlamannati, 2017). With arguments in either direction, it is entirely conceivable that any effects democracy might have on the environment could simply cancel out or otherwise be insignificant.

One thing that has commonly been observed is that the effect of democracy on deforestation rates tend to be the highest in nations transitioning to democracy (Imai et al., 2018). This result is often a consequence of using an Environmental Kuznet's Curve (EKC) model. The EKC hypothesis asserts that there is a quadratic relationship between the explanatory variable of interest (in our case this is democracy) and environmental outcomes. Specifically, we expect that deforestation rates would initially rise with increases in democracy, they would eventually reach a turning point threshold and begin to decrease with further increases in democracy. This relationship is illustrated in Fig. 1.

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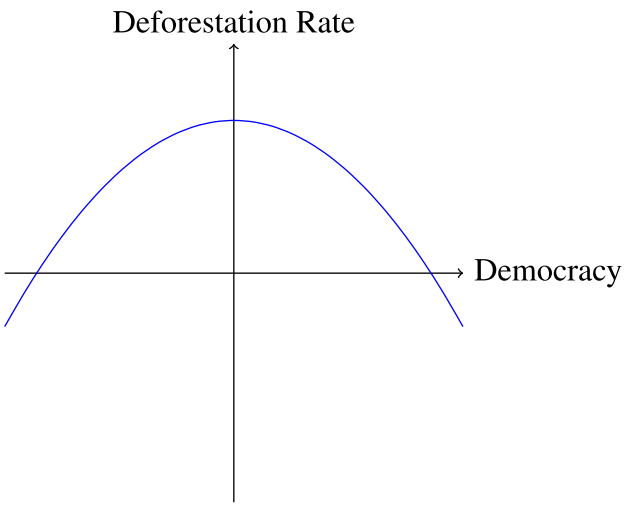

Fig. 1. An illustration of the relationship between democracy and deforestation rates according to the EKC hypothesis. As democracy initially increases the deforestation rate increases. Eventually the deforestation rate peaks and begins to decline with further increases in democracy.

While initial EKC studies found support of the EKC hypothesis for democracy and deforestation, more recent studies have shown the opposite relationship or no relationship at all (Choumert et al., 2013). In fact, one of the results we will present in this paper is that the time period covered by a data set directly affects whether or not we will find support for the EKC hypothesis.

When estimating the relationship between democracy and deforestation, careful attention must be paid to control variables. Omitted variable bias is a major concern. Specifically, income (as measured by GDP per capita) must be accounted for in regression models as democracy and income are closely correlated. Another major concern with EKC models is the model specification itself. EKC models are often subject to endogeneity concerns, so models such as differenced models or autoregressive models are best suited for studying the EKC hypothesis (Burnett et al., 2013).

One major study on the relationship between democracy and deforestation by Buitenzorgy and Mol (2011) found that after controlling for income, democracy did affect deforestation rates as expected under the EKC hypothesis. They use deforestation data which describes changes in forest cover from 1990 to 2000. Our objective in this paper is to build upon that study. First we replicate the data set used by Buitenzorgy and Mol (2011) and confirm their results. Once the replication study is complete, we create an updated data set for the time period 2000 to 2010 and re-run the analyses run by Buitenzorgy and Mol (2011). We then exploit this new, multi-time period data set by running panel data models to estimate the effect of democracy on deforestation rates. We further consider potential spatial spillover effects due to democracy which might arise from a democratic nation exploiting a developing neighbor with less developed institutions and property rights.

Based on our results we find not only that spillover effects are significant, but that we reject the EKC hypothesis for democracy and deforestation in the presence of spillover effects. Rather, democracy and the democracy spillover effect both indicate that democracy decreases deforestation rates.

The remainder of the paper is structured as follows. We begin with a comprehensive literature review in section 2. Subsequently, in section 3, we discuss the data set, how it was created, and how well we replicate the original data used in Buitenzorgy and Mol (2011). This includes the replication data and the newer data we use. Once the data has been thoroughly described, we describe the methodologies used in this paper in section 4, including a motivation of the differenced model that is used to provide an econometrically sound test for whether or not the EKC hypothesis holds for democracy and deforestation. With the methods described, we then present and discuss the results from each set of models in section 5. This includes the replication study (in which we find that the original results by Buitenzorgy and Mol (2011) were not robust after accounting for heteroskedasticity) and the updated models. Finally we conclude the paper with a highlight of our contributions in section 6.

2. Review of related literature

Many studies on the relationship between democracy and deforestation have been written over the past several decades. The results in the literature form something far from a consensus. Studies by Ehrhardt-Martinez et al. (2002) and Midlarsky (1998) have found that democracy contributes to deforestation. In a broader context, Mayer (2017) found that democracy leads to increased carbon dioxide and other emissions which in turn lead to a decrease in environmental quality. On the other hand, studies such as Li and Reuveny (2006), Shandra (2007b), and Shandra et al. (2012) found strong evidence showing that democracy decreases deforestation rates.

But the direct impact of democracy on deforestation does not tell the entire story. The choice of political attribute measured as an explanatory variable can greatly influence outcomes (Wehkamp et al., 2018). Political stability is also influential on forest cover (Kountouris et al., 2015). For example, Achour et al. (2018) studied the impact of the, 2011 Tunisian revolution on forest cover and found that the revolution led to not only democratic gains, but also a loss in forest cove The inclusion of appropriate control variables is also critical to the successful analysis of the relationship between democracy and deforestation. Ensuring that income levels are accounted for is paramount when studying this relationship (Rydning Gaarder and Vadlamannati, 2017; Esmaeili and Nasrnia, 2014). Urbanization is known to have a positive effect on deforestation (Nathaniel and Bekun, 2020). Remittances, however, actually have helped reduce deforestation, especially in middle income nations (Afawubo and Noglo, 2019). r. Measures of the strength of property rights, which are highly dependent upon political stability, are also critical. Stronger property rights have been linked to decreased rates of deforestation (Esmaeili and Nasrnia, 2014). Democracy can also facilitate public protection of forested areas. Protected areas are known to reduce loss of forest cover, even in non-democratic nations (Butsic et al., 2015). However, trade openness, which typically coincides with democracy, can also lead to the movement of dirty production processes and emissions therefrom from developed nations to developing nations when environmental regulations are put into effect. This result, called the creation of pollution havens, has been confirmed, e.g., recently by Kolcava et al. (2019).

The inclusion of appropriate control variables is also critical to the successful analysis of the relationship between democracy and deforestation. Ensuring that income levels are accounted for is paramount when studying this relationship (Rydning Gaarder and Vadlamannati, 2017; Esmaeili and Nasrnia, 2014). Urbanization is known to have a positive effect on deforestation (Nathaniel and Bekun, 2020). Remittances, however, actually have helped reduce deforestation,

Table 1
Summary statistics for the data. We present summary statistics for both the 1990–2000 time period as well as from 2000 to 2010. There are a total of 154 nations represented in the data set.

Variable	1990–2000 Mean	2000–2010 Mean	Change
Deforestation Rate	0.077%	0.221%	0.144
Democracy	2.226	3.356	1.130
Education	58.876%	65.722%	6.846
Rural Population	48.801%	45.566%	−3.325%
ln(Land Area)	15.507	15.507	–
Control of Corruption	−0.117	−0.146	−0.029
ln(GDP per capita)	8.712	8.936	0.224
Tariff Rate	11.684%	7.624%	−4.059%
Agricultural Land Growth Rate	0.101%	0.039%	−0.062%
Urbanization	51.199%	54.434%	3.235%

especially in middle income nations (Afawubo and Noglo, 2019).

While the specific mechanisms by which democracy impacts deforestation are numerous, the validity and beneficiality of specific mechanisms depends on the nation in question, its characteristics, and its level of democracy. Higher income nations are typically experiencing reforestation (Caravaggio, 2020b). An increased presence of non-governmental organizations (NGOs) is known to help decrease deforestation rates (Shandra, 2007a). However, NGOs are not uniformly distributed across nations and NGOs are known to be more effective at reducing deforestation rates in nations with higher levels of democracy (Shandra, 2007a).

Shandra et al. (2009) showed that forest products tend to flow inequitably from poor nations to rich nations, providing evidence that wealthier nations exploit the forest resources of less wealthy nations. But forest resource exploitation does not occur only at the national level. Within nation concerns of governing the commons in both developed and developing nations is a major concern for forest resource management (Ostrom, 1990). At the local level, illegal logging and agricultural encroachment often occurs in nations with weak enforcement systems (Azuela, 2004). Given that weak enforcement systems are most prominent among nations transitioning to democracy from more autocratic forms of governance, this implies that the relationship between democracy and deforestation may be nonlinear.

The most common model for studying the relationship between democracy and deforestation is the EKC model. The EKC model hypothesizes a nonlinear relationship between democracy and deforestation which takes the shape of an inverted "U". This model, however, is known to have several econometric concerns, most notably that it is not robust to models specification and is subject to endogeneity concerns (Lin and Liscow, 2013). In addition to these concerns, forest cover data for developing nations is often unreliable (Caravaggio, 2020a). To overcome these issues, a differenced model is a valid option for estimating the impact of democracy on deforestation within the context of the EKC hypothesis (Burnett et al., 2013).

Our paper studies the relationship between democracy and deforestation and en route tests the EKC hypothesis for democracy and deforestation. To do this, we not only replicate the work of Buitenzorgy and Mol (2011), but we also extend their results using more recent data and then attempt to validate these results using a differenced model. We find that model specification is critical to validating the EKC hypothesis for democracy and deforestation. That is, with a properly specified model, the EKC hypothesis is rejected in favor of a linear relationship between democracy and deforestation. This result is further confirmed in the presence of democracy spillover effects.

3. The data set

The data set used in this study begins with a replication of the data used in Buitenzorgy and Mol (2011). In that study the authors used data on deforestation rates from the Food and Agricultural Organization (2005) as the dependent variable. The deforestation rate for each nation is the percent change in forest cover from 1990 to 2000. The explanatory variable of interest was the Polity Index, a measure of how democratic a nation is, was sourced from Marshall et al. (2019). The remaining control variables are education (percent of eligible population enrolled in secondary school), rural population (proportion of people living in rural areas), land area (hectares), the control of corruption index, and income (gdp per capita based on purchasing power parity). These control variables all cover the time period from 1990 to 2000 and come from the The World Bank (2019) and the Food and Agricultural Organization (2005).

We used all of the same sources to replicate the data set used by Buitenzorgy and Mol (2011). Even though there may have been updates to data sets over time, we believe that the replicated data set very closely mimics the original data set based upon the similarity of the results from the replicated regression models (these will be presented in the Results section).

Once this data set was completed, we then create an updated version of the same variables from the same data sources but over the time period from 2000 to 2010. This time frame is chosen because the FAO data set looks at changes over each decade, thus this is the most recent data available. We also added additional variables for mean tariff rate on imports, mean growth rate in agricultural lands, and, for the sake of some EKC specific robustness checks, urbanization. These three new variables are included because agricultural land quite often comes from removing existing forest cover (Kuusela and Amacher, 2016), tariffs can affect openness and land allocation (Iwińska et al., 2019) and carbon intensities (Cary, 2020), and urbanization has been shown to be an important variable to use to test the EKC hypothesis in the context of deforestation (Ehrhardt-Martinez, 1998). Updated data along with the additional variables comes from the The World Bank (2019). Summary statistics for the data are presented below in Table 1.

In addition to running regression models, Buitenzorgy and Mol (2011) also performed two cluster analyses, one based on six categories for regime type (strong democracies, weak democracies, restricted democratic processes, authoritarian regimes, totalitarian regimes, and traditional monarchies), and a second based on three categories of democracy status (non-democracies, transitioning nations, and mature democracies). To perform the categorization of nations for the cluster analysis, we use use a similar classification system as our basis (West, 2013) before developing an algorithm for converting the basis classification system into one which mimics that of Buitenzorgy and Mol (2011). We develop this approach and algorithm because there was no detailed description of the classification method available in the original paper, and because the categories given in the basis classification system do not match the ones used by Buitenzorgy and Mol (2011).

The first algorithm uses the categories assigned to nations in the basis classification system and the polity index for that nation to assign each nation to a new category in the system used by Buitenzorgy and Mol (2011). The algorithm is defined below.

Algorithm 1 Six Group Classification Algorithm

```
if Basis Category == Absolute Monarchy OR Theocracy then
    Category ← Traditional Monarchy
    (Morocco and Bahrain are added to this list because they are specifically listed as Traditional Monarchies in Buitenzorgy and Mol (2011))
else if Basis Category == Totalitarian then
    Category ← Totalitarian Regime
else if Basis Category == Military then
    Category ← Authoritarian Regime
else
    if Polity Index ≥ 6.5 AND Standard Deviation of Polity Index ≤ 2 then
        Category ← Strong Democracy
    else if Polity Index ≥ -2.5 then
        Category ← Weak Democracy
    else if Polity Index ≤ -4 then
        Category ← Authoritarian Regime
    else
        Category ← Restricted Democratic Process
    end if
end if
```

Table 2
A comparison of the results of the classification schemes in the original paper and in this paper.

Category	Buitenzorgy & Mol	Replication
Traditional Monarchies (TM)	9	9
Totalitarian Regimes (TOT)	6	7
Authoritarian Regimes (AR)	37	33
Restricted Democratic Process (RDP)	14	14
Weak Democracies (DEM-W)	54	53
Strong Democracies (DEM-S)	38	38
Totals	158	154

The results of this algorithm are presented in Table 2 and compared against the classification data presented in Buitenzorgy and Mol (2011).

The second algorithm is much simpler as it classifies all nations into only three categories.

4. Methodology

The first set of models we run are for the replication of Buitenzorgy and Mol (2011). These models are simple OLS regression models with the deforestation rate as the dependent variable and consider data from 1990 to 2000. In addition to the regression models, the replication study also includes cluster analyses. Once these are complete, we repeat the OLS regression models and cluster analyses using data from 2000 to 2010. The OLS regression models take the form of Eq. 1 in which R denotes the deforestation rate, D denotes the polity index as a proxy for democracy, D^2 denotes the squared value of the polity index in order to test the EKC hypothesis, X denotes the set of control variables included to avoid omitted variable bias, ε denotes the residual, and i denotes the nation.

$$R_i = \beta X_i + \gamma D_i + \delta D_i^2 + \varepsilon_i \quad (1)$$

Algorithm 2 Three Group Classification Algorithm

```
if Category == Strong Democracy then
    2nd Category ← Mature Democratic Country
else if Category == Totalitarian Regime OR Authoritarian Regime OR Traditional Monarchy then
    2nd Category ← Non-democratic Country
else if Polity Index ≥ 4 AND Standard Deviation of Polity Index ≤ 4 then
    2nd Category ← Mature Democratic Country
else
    2nd Category ← Transitioning Country
end if
```

Once these analyses are completed, we then run a series of panel data regression models. These models include the same variables in the replication models along with tariff rate data and agricultural land growth rate data on the assumption that these are important omitted variables in the original study. These models take the form of Eq. 2 in which R denotes the deforestation rate, D denotes the polity index as a proxy for democracy, D^2 denotes the squared value of the polity index in order to test the EKC hypothesis, X denotes the set of controls, ε denotes the residual, and the indices i and t denote the nation and time period, respectively.

$$R_{i,t} = \beta X_{i,t} + \gamma D_{i,t} + \delta D_{i,t}^2 + \varepsilon_{i,t} \tag{2}$$

To address the concern of endogeneity, we next employ a differenced model. The differenced model simply considers the difference between the 2000–2010 data and the 1990–2000 data. The form the model takes is given in Eq. 3 where Δ denotes a change in the variable.

$$\Delta R_i = \beta \Delta X_i + \gamma \Delta D_i + \delta \Delta D_i^2 + \varepsilon_i \tag{3}$$

Finally, we re-run the panel data regression models and the differenced models with spatially weighted democracy terms to see if democracy had spillover effects on deforestation. This means that we are testing to see not only if the level of democracy in a given nation impacts its deforestation rate, but we are also testing to see if having more or less democratic neighbors impacts the deforestation rate of a given nation. These models are the same as the previous two sets of models but with additional terms for the average polity index for all neighbors of each nation. These values are obtained by forming a spatial weights matrix W and multiplying the matrix W by the vectors D and D^2. The spatial models for the panel data set take the forms of Eqs. 4 and 5, where j is also an index of nations (i.e., i and j refer to the same set).

$$R_{i,t} = \beta X_{i,t} + \gamma D_{i,t} + \delta D_{i,t}^2 + \theta \sum_{j \in J} W_{i,j,t} D_{j,t} + \phi \sum_{j \in J} W_{i,j,t} D_{j,t}^2 + \varepsilon_{i,t} \tag{4}$$

$$\Delta R_i = \beta \Delta X_i + \gamma \Delta D_i + \delta \Delta D_i^2 + \theta \sum_{j \in J} W_{i,j} \Delta D_j + \phi \sum_{j \in J} W_{i,j} \Delta D_j^2 + \varepsilon_i \tag{5}$$

5. Results and discussion

This section is divided into subsections as follows. First we cover the replication of Buitenzorgy and Mol (2011). In the second subsection we repeat the analyses from Buitenzorgy and Mol (2011) on more recent data to see if the results hold over time or are a product of the 1990s and not reliably extendable to the present. In the third subsection we present the results from the panel data econometric models and the differenced models. Finally, in the fourth subsection we present and discuss the results from the panel data models and the differenced models with spillover effects included.

In addition to incorporating spillover effects for democracy into our analyses, the panel data models and the first differenced models are a noteworthy contribution in their own rights. Previous results have relied on cross sectional data and methods. Given that forms of governance have changed drastically in many countries during the time period covered by this study, capturing these intertemporal realities is critical when assessing the relationship between democracy and deforestation. By using both panel data models and first differenced models, we directly incorporate the intertemporal reality of this relationship into our analyses.

5.1. The replication study

We begin the discussion of our results by presenting and discussing the results of the replication portion. We present this first to instill confidence into the reader that our choices of data and methodologies are consistent with the existing literature as this is an important part of the overall results presented in this paper.

We begin with the results of the regression models. Results are presented in Table 3. The results we obtain are very similar to those of Buitenzorgy and Mol (2011) with one major exception. When we use heteroskedasticity robust standard errors as opposed to non-robust standard errors, some of the estimated coefficients are no longer statistically significant. Nevertheless we can conclude several things from these models. First, we see that democracy increases deforestation rates. When we include the democracy squared term, we do not find statistically significant evidence for the EKC hypothesis. While the estimated coefficients for democracy squared were statistically significant in some of the models in the original study by Buitenzorgy and Mol (2011), once we account for heteroskedasticity we find that there is no support for the EKC hypothesis for democracy and deforestation. Thus, we conclude that if democracy has any effect on changes in forest cover, it is to increase deforestation.

The second contribution of the paper by Buitenzorgy and Mol (2011) is two cluster analyses. We replicate those analyses and present our results in Figs. 2 and 3. Our results are consistent with the original analyses and indicate some support for the EKC hypothesis for democracy and deforestation during the time period from 1990 to 2000.

5.2. The replication with new data

In the previous subsection we briefly presented the results from the replication portion of this paper. We confirmed many of the results in Buitenzorgy and Mol (2011) and found some limited evidence in favor of the EKC hypothesis for democracy and deforestation, but we also found that this evidence was much weaker when we corrected our standard errors with heteroskedasticity robust standard errors. In this section we present the same analyses but with more recent data. The original study used the Food and Agricultural Organization (2005) which contained forest cover data for 1990–2000. The updated version of this data set (Food and Agricultural Organization, 2011) covers the time period from 2000 to 2010.

The results from this section further support the EKC hypothesis for democracy and deforestation. In fact, these results are still statistically significant even after accounting for heteroskedasticity robust standard errors. The estimated coefficients for democracy and democracy squared indicate a turning point between 1 and 4 for the polity index.[1] This indicates that deforestation rates peak in the range of polity index values associated with nations transitioning to democracy. This result is consistent with the notion that as countries transition to democracy, there is an increase in the exploitation of natural resources. This exploitation often occurs as a consequence of the country "opening up" to investment from foreign companies who seek to exploit cheap labor and resources for profit. This phenomenon has been called the eco-colonial land grab (Okoh, 2015). Results from these regression are presented in Table 4.

We perform the cluster analyses with the newer data. We still see evidence of the EKC hypothesis for democracy and deforestation. However, the shape of the curve is much more subdued in comparison with the cluster analysis from the replication portion of this paper. This indicates that we might still expect to find evidence for the EKC hypothesis for democracy and deforestation during the time period from 2000 to 2010. The results of the cluster analyses are shown in Figs. 4 and 5.

5.3. Fully specified models

While we found evidence supporting the EKC hypothesis for democracy and deforestation in both time periods on their own, it is

[1] Turning points in an EKC model are calculated as $-\beta_1/2\beta_2$ where β_1 and β_2 are the estimated coefficients for Democracy and Democracy Squared, respectively.

Table 3
Results from the replication models. Estimates that are significant at the (10%, 5%, and 1%) level are denoted by (*, **, and ***), respectively. Heteroskedasticity robust standard errors are presented in parentheses.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	0.963***	−2.371	−2.106	−1.869	−1.859	−2.620	0.989***
	(0.315)	(2.242)	(2.203)	(2.512)	(2.473)	(2.710)	(0.288)
Democracy	0.048	0.159***	0.140***	0.136***	0.138**	–	–
	(0.046)	(0.047)	(0.049)	(0.050)	(0.059)	–	–
Democracy Squared	−0.022***	−0.004	−0.008	−0.003	−0.003	–	–
	(0.008)	(0.007)	(0.006)	(0.006)	(0.005)	–	–
Education	–	−0.027***	−0.030***	−0.027***	−0.026***	−0.017**	–
	–	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	–
Rural Population	–	0.030***	0.032***	0.026*	0.025*	0.023*	–
	–	(0.011)	(0.012)	(0.015)	(0.014)	(0.013)	–
Ln(Land)	–	0.156	0.158	0.160	0.163	0.171	–
	–	(0.103)	(0.105)	(0.111)	(0.126)	(0.139)	–
Control of Corruption	–	−0.384	–	–	–	–	–
	–	(0.261)	–	–	–	–	–
Ln(GDP per capita)	–	–	–	−0.030	−0.037	−0.002	−0.078**
	–	–	–	(0.018)	(0.063)	(0.054)	(0.034)
Ln(GDP per capita squared)	–	–	–	–	7.41e-05	−4.04e-04	1.02e-04
	–	–	–	–	(0.001)	(0.001)	(0.000)
N	154	145	145	142	142	142	149
Adjusted R^2	0.082	0.353	0.347	0.371	0.367	0.303	0.211

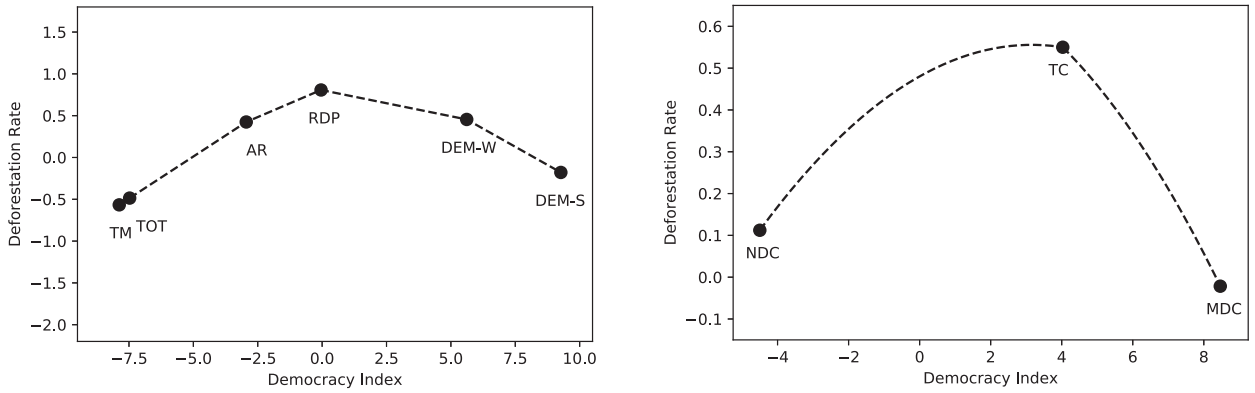

Fig. 2. A plot of the relationship between democracy and deforestation by cluster. This plot contains the results for the cluster analysis with six categories and provides some visual evidence of the EKC during the time period from 1990 to 2000.

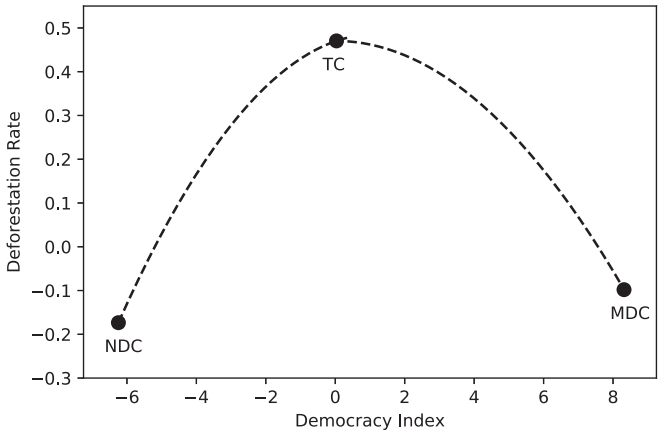

Fig. 3. A plot of the relationship between democracy and deforestation by cluster. This plot contains the results for the cluster analysis with three categories and provides some visual evidence of the EKC during the time period from 1990 to 2000.

worthwhile to confirm this result with the full panel data set. A simple cross sectional analysis does not capture changes over time. This is why it is crucial to see if the results from the cross sectional analyses are robust to a panel data model approach. It is even more important to compare these results to the results from a differenced model in order to ensure that the results are robust to model specification and not affected by endogeneity problems. For this reason, the differenced models are the focus of this paper. We first present the results from the panel models before showing the results from the differenced models.

When running the panel data models we include all combinations of fixed effects for region (continent) and time period. We still find support for the EKC hypothesis in the full panel data set. Turning points are estimated between 3.65 and 4.45, well within the range of weak democracies on the polity index. This is slightly higher and more precise than what we saw in the single time period models. These results indicate that the exploitation of forest resources is most severe in newly democratic nations. This result is again consistent with the notion that emerging democracies are easily exploited by wealthier nations in eco-colonial land grabs. Interestingly, we did not find increases in the growth rate of land allocated to agriculture statistically significant. The results from the panel data models are presented below in Table 5.

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Turning our attention to the differenced models, we find a different story. First, we do not find evidence for the EKC hypothesis for democracy and deforestation. In fact, the sign of the estimated coefficients

Table 4
Results from the replication models with updated data. Estimates that are significant at the (10%, 5%, and 1%) level are denoted by (*, **, and ***), respectively. Heteroskedasticity robust standard errors are presented in parentheses.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant	0.794***	1.391	1.456	1.707	1.734	1.386	0.719***
	(0.188)	(1.192)	(1.201)	(1.311)	(1.296)	(1.298)	(0.186)
Democracy	0.031	0.063**	0.056**	0.053**	0.055**	–	–
	(0.019)	(0.025)	(0.023)	(0.023)	(0.024)	–	–
Democracy Squared	−0.014***	−0.008**	−0.011***	−0.012***	−0.011***	–	–
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	–	–
Education	–	−0.010***	−0.010***	−0.010***	−0.010***	−0.009***	–
	–	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	–
Rural Population	–	0.002	0.004	0.004	0.002	8.33e-04	–
	–	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	–
Ln(Land)	–	−0.032	−0.030	−0.041	−0.034	−0.020	–
	–	(0.067)	(0.067)	(0.071)	(0.074)	(0.075)	–
Control of Corruption	–	−0.214*	–	–	–	–	–
	–	(0.116)	–	–	–	–	–
Ln(GDP per capita)	–	–	–	0.004	−0.013	−0.025*	−0.047***
	–	–	–	(0.007)	(0.017)	(0.013)	(0.011)
Ln(GDP per capita squared)	–	–	–	–	1.87e-04	1.89e-04	3.90e-04***
	–	–	–	–	(0.000)	(0.000)	(0.000)
N	154	146	146	143	143	143	149
Adjusted R^2	0.108	0.173	0.169	0.156	0.155	0.113	0.097

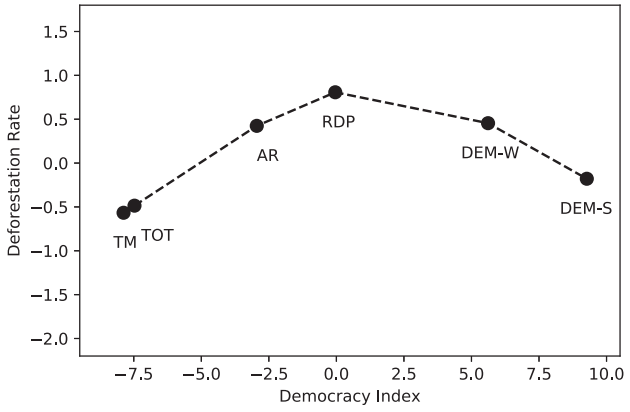

Fig. 4. A plot of the relationship between democracy and deforestation by cluster. This plot contains the results for the cluster analysis with six categories and provides some visual evidence of the EKC during the time period from 2000 to 2010.

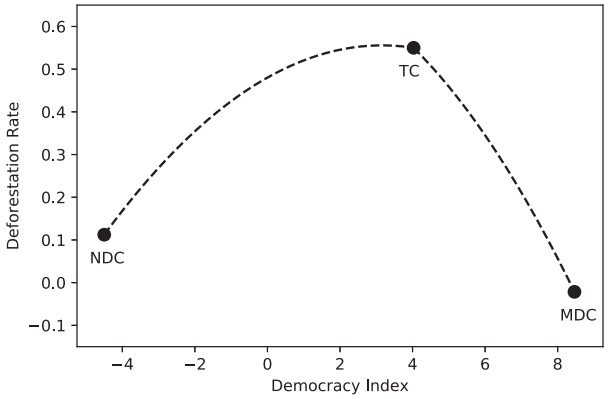

Fig. 5. A plot of the relationship between democracy and deforestation by cluster. This plot contains the results for the cluster analysis with three categories and provides some visual evidence of the EKC during the time period from 2000 to 2010.

for both democracy and democracy squared are reversed. Only the democracy term is statistically significant. Together, this means that democracy leads to a decrease in deforestation. Surprisingly, we also find that increases in the change in the growth rate of land allocated to agriculture negatively impacts deforestation rates, though this effect is only statistically significant at the 10% level once fixed effects are included in the model. These results are shown in Table 6.

5.4. Spatial models

In the first three subsections we presented evidence for the EKC hypothesis for democracy and deforestation. Specifically, we confirmed the existing literature which supports the EKC hypothesis for democracy and deforestation for both the 1990–2000 and 2000–2010 time periods. By combining the data from both of these time periods, we created a panel data set and confirmed the EKC hypothesis for democracy and deforestation for the panel data set. However, when introducing the differenced model that serves as the core contribution of this paper, we find that the EKC hypothesis for democracy and deforestation is eschewed in favor of a strict decrease in deforestation rates as democracy levels are increased.

But a critical component has been left out thus far. Since the existing literature on democracy and deforestation fails to consider the potential spillover effects of democracy, we now provide the results from the main model in this paper, we present spatial variants of the panel data and differenced models which include spillover effects for democracy.

We might expect to find evidence of spillover effects from democracy because more democratic neighbors are likely to have more developed property rights which protect forested land, but are also likely to invest in the natural resources of neighboring countries with less stringent property rights. An example of this was found by Fuller et al. (2019) who showed that there are positive spillover from implementing land use restrictions. Model specification is also critical. The EKC hypothesis is known to have issues in standard panel models and is better estimated using differenced models (Burnett et al., 2013). As it turns out, the results from the spatial panel models and the spatial differenced models differ from one another.

In the spatial panel models (results presented in Table 8) we find weak evidence in favor of the EKC hypothesis for democracy and deforestation. However, in the spatial differenced models, the key contribution of this paper, we find a very interesting result (results presented in Table 7).

Firstly, we find that a positive change in democracy leads to a

Table 5
Results from the panel data models. Estimates that are significant at the (10%, 5%, and 1%) level are denoted by (*, **, and ***), respectively. Heteroskedasticity robust standard errors are presented in parentheses.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	−1.376	0.436	−1.508	−1.299	0.555	−1.432
	(2.281)	(2.284)	(2.350)	(2.226)	(2.199)	(2.293)
Democracy	0.080**	0.089**	0.076**	0.077**	0.086**	0.073**
	(0.039)	(0.037)	(0.037)	(0.036)	(0.034)	(0.034)
Democracy Squared	−0.011**	−0.010**	−0.010**	−0.010**	−0.010**	−0.010**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Education	−0.010**	−0.016***	−0.011**	−0.010**	−0.017***	−0.011**
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Rural Population	0.018*	0.012	0.018*	0.019*	0.012	0.019*
	(0.009)	(0.009)	(0.009)	(0.010)	(0.009)	(0.010)
Ln(Land)	0.059	0.056	0.066	0.060	0.058	0.068
	(0.095)	(0.098)	(0.100)	(0.095)	(0.099)	(0.100)
Ln(GDP per capita)	3.80e+8	3.73e+8	3.68e+8	4.41e+8	4.31e+8	4.32e+8
	(5.82e+8)	(5.98e+8)	(5.80e+8)	(6.10e+8)	(6.28e+8)	(6.08e+8)
Ln(GDP per capita squared)	−1.90e+8	−1.86e+8	−1.84e+8	−2.21e+8	−2.15e+8	−2.16e+8
	(2.91e+8)	(2.99e+8)	(2.90e+8)	(3.05e+8)	(3.14e+8)	(3.04e+8)
Tariff Rate	−0.011	−0.007	−0.006	−0.012	−0.007	−0.007
	(0.014)	(0.014)	(0.014)	(0.015)	(0.014)	(0.014)
Ag Land Rate	–	–	–	−0.081	−0.080	−0.086
	–	–	–	(0.107)	(0.112)	(0.110)
Time Period Fixed Effects	–	✓	✓	–	✓	✓
Region Fixed Effects	✓	–	✓	✓	–	✓
N	253	253	253	253	253	253
Adjusted R^2	0.244	0.221	0.244	0.243	0.220	0.244

Table 6
Results from the differenced models. Estimates that are significant at the (10%, 5%, and 1%) level are denoted by (*, **, and ***), respectively. Heteroskedasticity robust standard errors are presented in parentheses. The natural log of land is not a change in land area but simply a weighted fixed effect for nations.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	2.120	1.968	2.037	1.549	1.458	1.536
	(1.558)	(1.469)	(1.469)	(1.487)	(1.434)	(1.425)
Democracy	−0.151**	−0.139**	−0.141**	−0.140*	−0.131*	−0.133*
	(0.076)	(0.070)	(0.071)	(0.079)	(0.075)	(0.076)
Democracy Squared	0.009	0.005	0.006	0.013	0.009	0.009
	(0.011)	(0.012)	(0.012)	(0.013)	(0.014)	(0.014)
Education	0.002	0.005	0.005	0.004	0.006	0.006
	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Rural Population	0.040	0.048	0.045	0.044	0.048	0.045
	(0.052)	(0.054)	(0.054)	(0.051)	(0.052)	(0.053)
Ln(Land)	−0.109	−0.106	−0.111	−0.100	−0.099	−0.104
	(0.097)	(0.094)	(0.093)	(0.098)	(0.095)	(0.095)
GDP per capita	1.99e-05	4.69e-05	4.55e-05	4.83e-05	6.78e-05	6.62e-05
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D*GDP	7.19e-06	1.25e-05	1.15e-05	1.88e-06	6.29e-06	5.28e-06
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ag Land Rate	–	−0.250**	−0.243**	–	−0.219*	−0.214*
	–	(0.123)	(0.122)	–	(0.121)	(0.121)
Tariff Rate	–	–	−0.007	–	–	−0.006
	–	–	(0.011)	–	–	(0.010)
Time Period Fixed Effects	–	–	–	–	✓	✓
Region Fixed Effects	–	–	–	✓	–	✓
N	154	154	154	154	154	154
Adjusted R^2	0.032	0.060	0.055	0.072	0.092	0.086

decrease in the deforestation rate. This effect is the dominant effect even though we have controlled for changes in income as measured by GDP per capita. The spillover effect for democracy squared is negative and statistically significant. This indicates that being surrounded by emerging democracies is relatively worse for a nation when it comes to deforestation. Being surrounded by mature democracies has a negative impact on deforestation rates. This could be evidence that stricter environmental laws from mature democracies could help to protect forested lands in neighboring countries.

The spillover effect is particularly interesting because only the quadratic term was statistically significant. This means that ideal neighbors are either mature democracies or non-democratic nations. This can be explained by the relative stability in economic practices that each extreme can allow for. Transitioning countries, i.e., countries striving towards full democracy, are often subject to natural resource exploitation from mature democracies due to foreign investment. Such nations are also typified by an increase in demand for natural resources and may encourage increased harvesting of forest products in their neighbors. This, compounded with the fact that stable, mature democracies are more likely to implement national and regional environmental protection policies illustrates the importance of the spillover effects.

In addition to the results on democracy and spillover effects, we also see that when fixed effects are included the term for agricultural land growth rate is no longer significant. This result makes more sense than the coefficient for agricultural land growth rates in the non-spatial

Table 7
Results from the spatial differenced models. Estimates that are significant at the (10%, 5%, and 1%) level are denoted by (*, **, and ***), respectively. The natural log of land is not a change in land area but simply a weighted fixed effect for nations.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.688	0.671	0.739	0.154	0.295	0.288
	(1.156)	(1.130)	(1.114)	(1.250)	(1.258)	(1.265)
W*Democracy	−0.145	−0.156	−0.155	−0.068	−0.083	−0.082
	(0.125)	(0.124)	(0.124)	(0.141)	(0.141)	(0.141)
W*Democracy Squared	−0.019*	−0.017*	−0.017*	−0.019*	−0.017*	−0.017*
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Democracy	−0.237***	−0.228***	−0.229***	−0.210***	−0.204***	−0.206***
	(0.070)	(0.064)	(0.064)	(0.069)	(0.066)	(0.067)
Democracy Squared	0.011	0.008	0.009	0.014**	0.011*	0.012*
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Education	0.004	0.006	0.005	0.003	0.005	0.004
	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)
Rural Population	0.064*	0.072**	0.069*	0.077*	0.081*	0.077*
	(0.036)	(0.037)	(0.038)	(0.042)	(0.041)	(0.043)
Ln(Land)	0.018	0.015	0.010	0.026	0.023	0.018
	(0.073)	(0.072)	(0.070)	(0.074)	(0.073)	(0.071)
GDP per capita	1.07e-05	3.33e-05	3.21e-05	4.98e-05	6.46e-05	6.31e-05
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
D*GDP	1.52e-05	1.83e-05	1.69e-05	6.59e-06	9.36e-06	7.81e-06
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ag Land Rate	–	−0.156*	−0.149*	–	−0.122	−0.114
	–	(0.087)	(0.088)	–	(0.092)	(0.093)
Tariff Rate	–	–	−0.008	–	–	−0.008
	–	–	(0.008)	–	–	(0.008)
N	137	137	137	137	137	137
Adjusted R^2	0.110	0.122	0.118	0.135	0.140	0.136

Table 8
Results from the spatial panel models. Estimates that are significant at the (10%, 5%, and 1%) level are denoted by (*, **, and ***), respectively.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.376	2.900*	0.357	0.368	2.880*	0.347
	(1.633)	(1.531)	(1.632)	(1.622)	(1.515)	(1.620)
W*Democracy	0.013	0.013	0.006	0.012	0.011	0.005
	(0.023)	(0.024)	(0.023)	(0.023)	(0.024)	(0.023)
W*Democracy Squared	−0.007	−0.007	−0.007	−0.007	−0.007	−0.007
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Democracy	0.044*	0.062***	0.040*	0.043*	0.058***	0.037*
	(0.023)	(0.023)	(0.023)	(0.023)	(0.022)	(0.023)
Democracy Squared	−0.005*	−0.005	−0.006*	−0.005*	−0.005*	−0.006*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Education	−0.014**	−0.018***	−0.014**	−0.014**	−0.019***	−0.014**
	(0.006)	(0.005)	(0.006)	(0.006)	(0.005)	(0.006)
Rural Population	0.010	0.003	0.010	0.011	0.003	0.011
	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.009)
Ln(Land)	0.037	0.040	0.038	0.037	0.041	0.038
	(0.053)	(0.050)	(0.053)	(0.053)	(0.050)	(0.052)
Ln(GDP per capita)	6.24e+8	5.18e+8	6.22e+8	7.42e+8	6.53e+8	7.47e+8
	(5.87e+8)	(5.91e+8)	(5.88e+8)	(6.15e+8)	(6.25e+8)	(6.19e+8)
Ln(GDP per capita squared)	−3.12e+8	−2.59e+8	−3.11e+8	−3.71e+8	−3.27e+8	−3.74e+8
	(2.94e+8)	(2.95e+8)	(2.94e+8)	(3.07e+8)	(3.13e+8)	(3.09e+8)
Ag Land Rate	–	–	–	−0.080	−0.092	−0.085
	–	–	–	(0.081)	(0.082)	(0.081)
Time Period Fixed Effects	–	✓	✓	–	✓	✓
Region Fixed Effects	√	–	✓	✓	–	✓
N	255	255	255	255	255	255
Adjusted R^2	0.277	0.251	0.277	0.277	0.252	0.277

models.

5.5. Robustness checks

We mention here that our results are robust to several different specifications of the democracy spillover effect. These different specifications include the magnitude of the difference of the average weighted value of democracy in neighboring nations and whether or not the average weighted neighboring value of democracy is greater than the value of democracy in the nation itself. However, our results did not provide evidence in support of the EKC hypothesis for democracy and deforestation.

In addition to testing for the robustness of our results against alternative specifications, we also test for robustness of the EKC hypothesis with respect to urbanization. Urbanization has been shown to be, in the case of forest cover, a potentially preferable measure for development (Ehrhardt-Martinez, 1998). Therefore we run additional models which include urbanization and urbanization squared where urbanization is measured as the percentage of people living in urban areas. Specifically, we run the models outlined in this paper as well as the initial robustness checks for alternative specifications of the democracy spillover effect once more with both democracy and urbanization terms, and a second

additional time with urbanization fully taking the place of democracy as an alternative measure of development.

We find several notable things here. First, both urbanization and urbanization squared are statistically insignificant across all models, whether democracy is included as well or if urbanization took the place of democracy in the models. Second, the remaining variables are robust to the inclusion of urbanization in the models. This is most important for democracy as, per our findings, democracy is the better choice of variable, at least when considering a panel of nations consisting of the majority of all nations in the world.

6. Conclusion

In this paper we used expanded data and both panel data models and first differenced models to study the relationship between democracy and deforestation. By including spillover effects in our models and using an appropriate econometric framework for the EKC hypothesis, we found that gains in democracy lead to decreases in deforestation rates. We also found that having highly democratic neighbors also leads to decreases in deforestation rates. However, we did not find evidence supporting the EKC hypothesis for democracy and deforestation.

The result that democracy leads to decreased deforestation confirms some of the existing literature which claims that democracy leads to increased concern about environmental outcomes combined with a greater degree of political involvement. The spillover effects from democratic neighbors lend evidence that regional collaboration in environmental protection and the relatively reduced demand for natural resources relative to output exhibited by wealthier, mature democracies contribute to decreased deforestation rates.

Nations transitioning to democracy, however, are typified by increased demand for natural resources as their economic growth is driven by manufacturing rather than services as is the case in mature democracies. Our results indicate that having a neighbors that are in this transitory state can lead to increased harvesting of forest products, most likely to profit off of the increased demand for natural resources in the neighboring nation.

Future research can expand on this paper by building on the results on the spillover effects. In particular, it would be beneficial to understand more about how other characteristics of neighboring nations affect deforestation rates. Additionally, this type of spillover effect approach could be useful in studying forest health for specific forests.

Furthermore, satellite data could be used to provide a more reliable measure of deforestation. The FAO data used in this study is known to have certain limitations. For instance, data for developing nations is not widely available and standards and assumptions varied widely, thereby establishing a degree of unreliability (Food and Agricultural Organization, 2001).

From a policy standpoint, this study is not without merit. The relationship between democracy and deforestation derived in our models indicates that political structures and regimes play a pivotal role in shaping the nature of forest activities. Moreover, the implications vary for developing, emerging, and developed economies. For instance, some regions, such as the developing economies of Sub-Saharan Africa (SSA), the Middle East, and Southeast Asia are characterized by the presence of weak democratic structures and environmental regulations that centers around deforestation. Thus, appropriate forestry policy should be founded in promoting and stabilizing democracy in these blocs. This will help to address both the domestic effects and the spillover effects of democracy on deforestation. By reflecting the impact on afforestation on climate change mitigation, this position is in line with the United Nations Sustainable Development Goals 13. In summary, our analysis finds that democratic institutions should be reinforced in order to strengthen and stabilize forest conservation and by extension preserve the environment.

Author statement

Michael Cary – Conceptualization, Data Curation, Formal Analysis, Methodology, Software, Writing – original draft, Writing – review & editing.

Festus Victor Bekun – Conceptualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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