Environ Resource Econ (2016) 64:445–463
DOI 10.1007/s10640-015-9880-6

Changing Political Regimes and Tropical Deforestation

Olli-Pekka Kuusela · Gregory S. Amacher

Accepted: 25 January 2015 / Published online: 25 February 2015

Abstract Expansion of agriculture is a main cause of tropical deforestation. Government policies and weak property rights contribute to this process by encouraging landowners and landless to accelerate land clearing. Using panel data common to previous studies, we add the dimension of new political regimes, democratic and non-democratic, and investigate how the rate of agricultural land expansion in tropical countries depends on the nature and persistence of each regime. We find that both new autocratic and democratic regimes have accelerated the expansion of agricultural land, thus yielding support to some of the findings in the earlier literature. Interesting differences emerge between regions, with the impact being most pronounced in Latin America. We interpret these results mainly in the context of increasing tenure and ownership insecurity, which in turn is driven by the tendency of new regimes to implement land reforms as a form of social and economic policy or voter payback. The argument is developed more formally using a simple competitive land use model that incorporates political regime dependent confiscation risk and agricultural subsidy policy.

Keywords Agricultural expansion · Democracy · Autocracy · Political economy · Tenure risk · Land reform

1 Introduction

Tropical deforestation and its underlying causes have been an area of active research at least for the past three decades. It is widely agreed that the main driver of forest loss has been

This paper is based on a chapter from Kuusela's dissertation.

O.-P. Kuusela (✉)
Natural Resources Institute Finland (Luke), Latokartanonkaari 9, 00790 Helsinki, Finland
e-mail: olli-pekka.kuusela@luke.fi

G. S. Amacher
Department of Forest Resources and Environmental Conservation,
Virginia Tech, Blacksburg, VA 24060, USA
e-mail: gamacher@vt.edu

the rapid expansion of agricultural land. Other significant causes are road building, illegal logging, industrial harvesting through concessions, and fuelwood collection by local communities (Pfaff et al. 2010). Population pressures and economic development have also been commonly identified as important overall drivers. In many instances, however, the actions and policies of the governments, in addition to institutional characteristics of the countries, certainly work to magnify the extent of deforestation (Ross 2001). Insecure property rights and subsidies for agriculture favor land clearing over keeping native or plantation forests. Political instability, perceived through quick turnover of regimes, and accompanying ownership uncertainty further reduce the profitability of long term investments, such as forestry, favoring instead some form of extensive agriculture (Bohn and Deacon 2000).

A considerable number of tropical forest countries have gone through some degree of political upheaval, such as revolutions and military coups, during the past half century. For example, the first part of 1990s witnessed multiple democratization processes in Africa alone, and the Latin American countries have been oscillating between autocratic and democratic regimes since the Second World War. The ownership of productive land has frequently been at the core of the controversial issues surrounding postcolonial countries (De Janvry 1981; Prosterman and Riedinger 1987). To consolidate their power, or to preserve old privileges, new political regimes have recurrently enacted policies to redistribute land, commonly including provisions granting land ownership to migrants who clear forests.[1] The effects of these land reforms on tropical deforestation in turn may depend on the success and persistence of each new regime in power.

The purpose of this paper is to highlight the impact of the political economy on tropical deforestation from a perspective that extends past work (e.g., Bohn and Deacon 2000; Barbier 2001; López and Galinato 2005a; Buitenzorgy and Mol 2011). Using panel data and robust estimation methods, we examine how changes in political regime type affect the rates of tropical deforestation through agricultural land expansion. We propose a simple dynamic competitive land use model that captures the main effect of new political regimes on the economy's land allocation decision. New regimes may cause changes in relative land rents either through regime dependent land confiscation risk or through changes in agricultural subsidies, or both. This model and its predictions form the theoretical basis for our empirical investigation that in turn is closely related to Barbier (2001) and Rodrik and Wacziarg (2005).[2]

Although new regimes may enact land reforms for various reasons, some common threads have been pointed out in the literature. For example, a new autocratic regime might implement a land reform in order to appease the poor majority and thus prevent the possibility of a future revolution (Acemoglu and Robinson 2001).[3] Similarly, Grossman (1994) models land reforms as an optimal response on behalf of the landowning class that faces a "threat of extralegal appropriation of land rents".[4] On the other hand, redistribution of wealth is also in

[1] These reforms have been varying in their scale and scope, and in underlying intentions. Some have included direct expropriation and redistribution of private land, whereas others have aimed at encouraging peasants to colonize frontier lands. Adams (1995) observes that many historical land reforms in tropical countries have been purely opportunistic in their motives.

[2] In our model, political regimes exert effort to stay in power. This in turn may have an influence on the relative land rents from agriculture and forests. Since the direction of change in land rents is a priori unknown, we propose an econometric model that is closely linked to our analytical model to estimate and test this relationship based on historical data on land use.

[3] These mostly modest land reforms have been carried out with the support of the landowning class in the hopes of preventing subsequent more severe infringement of their land holdings (Adams 1995).

[4] Pfaff (1999) describes how in Brazil the military regime's push to colonize the Amazonian Basin in the 1970s was related to their effort to reduce pressures for social unrest due to growing population.

the interest of democratic regimes since they need to consolidate support among the poor and also cater to the ambitions of the majority (Midlarsky 1998). As in the case of autocracies, the most obvious way to redistribute wealth is to enact a land reform or allow access to public lands. Landless people can then claim an ownership stake on underdeveloped land by converting it to more productive uses like agriculture (Mendelsohn 1994).[5]

Most recently, Buitenzorgy and Mol (2011) examine the causal relationship between democratization and deforestation in cross-sectional setting using regime data compiled by Polity IV Project.[6] We too make use of the Polity IV project to encode a set of regime transition indicator variables in a panel data context. This allows us to derive more reliable coefficient estimates and distinguish between new and established regimes. The same empirical strategy was recently applied by Rodrik and Wacziarg (2005) to identify the impact of democratization on economic growth. Buitenzorgy and Mol (2011) combined forest cover data for the developed and developing world, but our work instead concentrates on explaining the expansion of agricultural land in tropical forest countries, and we go beyond cross sectional data by using a panel spanning 66 tropical countries from 1961 to 2008.[7] In a related work, Ferreira and Vincent (2010) examine the relationship between governance indices and timber harvests in developing countries. They too use panel data but the focus of their study differs from ours.

Our main finding is that both new democratic and autocratic regimes are statistically and quantitatively significant causes of higher rates of agricultural land expansion in tropical countries. The expansion of agriculture in turn drives tropical deforestation at the agricultural margin. In terms of our analytical model, relative rents from agriculture become higher after a regime change, thus expanding the agricultural margin at the expense of forests. Our results give support to the findings in Barbier (2001) where political instability was shown to be a significant and positive cause of agricultural land expansion. Our approach, however, enables us to identify the effects of both autocratic and democratic regime changes and their persistence on agricultural land expansion. We also make a contribution to the recent literature on the effect of democratization vs. economic growth on environmental outcomes (e.g., Midlarsky 1998; Buitenzorgy and Mol 2011). We find that new democratic regimes have a tendency to accelerate the expansion of agricultural land at least in certain regions, whereas established democracies do not. We furthermore find that higher income levels as measured by GDP translate to decreased agricultural land expansion in Latin America but the opposite holds in Africa. Finally, corruption control plays an interesting role through its interaction with the level of income and these effects differ across regions.

There are several ways to interpret the empirical results in the context of our theory model. First, the actions of new regimes reduce land ownership security through political

[5] Binswanger (1991) and Alston et al. (2000) provide evidence that such land policies in Brazil have contributed to deforestation through conflicting interests and land clearing incentives. The landowners expelled tenants and embarked on expanding extensive ranching activities after learning about land reform plans (Deininger and Binswanger 1999). In Cameroon the expectations of the 1974 land reform, where the government was planning to confiscate parts of the community forests for commercial exploitation, led villagers to rapidly expand croplands in order to establish ownership claim (Karsenty 2010).

[6] Bohn and Deacon (2000) also employ a similar type of an approach to identify the political factors influencing the investment environment. Their data on political attributes, however, come from a different source and the results with respect to deforestation are based on a limited cross-section study.

[7] Barbier (2001) and Barbier and Burgess (2001) recommend using agriculture land data because of problems with the reliability of existing forest cover data. Remote sensing data have recently become more readily available for some tropical countries, but these data are still too limited for the purpose of this study.

instability and government policies that encourage land conversion.[8] The same underlying cause of deforestation has been discussed extensively in the past literature (e.g. Deacon 1994, 1995, 1999; Mendelsohn 1994; Bohn and Deacon 2000; Amacher et al. 2009). For example, Mendelsohn (1994) demonstrates that even a small increase in the probability of confiscation leads squatters to favor more "destructive" forms of agriculture.[9] Second, new regimes may invest in road building near the agricultural margin and provide direct subsidies to farmers, thus accelerating the deforestation process by lowering land access costs (Chomitz et al. 2007). For example, Barbier (2011) makes the observation that the expansion of agriculture to environmentally fragile areas seems to be driven by growing number of rural poor. Finally, cultivation driven deforestation may also occur through development policies aimed at improving the efficiency of the country's resource use (Berry and Cline 1979). For example, new regimes may want to increase the output of the domestic agricultural sector. The skewed distribution of ownership, however, has led to a situation where large tracts of productive land lie idle, while sustenance farmers are forced to find living on marginal, and often environmentally fragile, lands (Deininger and Binswanger 1999). Thus land clearing subsidies or direct expropriation, where previously underused land areas are given to landless poor, potentially leads to a higher utilization rate of the land. Redistribution of land can thus lead to land clearing in the form of slash-and-burn agriculture, where areas previously deemed as unprofitable for agriculture are now converted to crop production by the new users.[10]

The structure of this paper is as follows. In the next section, we present a simple model of competitive land uses that forms the basis for our empirical examination. In Sect. 3 we outline our empirical strategy and the econometric model. Section 3 describes the data and the fifth presents the results with a discussion, while the last section concludes.

2 Dynamic Land Use Model

This section presents a simple dynamic model of competitive land use that captures the effect of a new political regime on deforestation process. The goal here is to build a parsimonious analytical framework that can then be used to motivate our econometric model and to interpret the empirical results in the subsequent sections.

Land ownership and the type of land use are important factors determining the success of different political regimes. Suppose that political regime i, once in power, maximizes the expected rents from staying in power by influencing the relative land rents from agriculture and forests. For example, regime i may deem that the expansion of agriculture at the expense of forests best advances its own goal of staying in power. To change the relative profits from different land uses, the political regime may directly subsidize agriculture, invest in infrastructure projects like roads in frontier areas, or make it easier to receive a legal land title if the land user practices agriculture. Regime i's effort is captured by a variable ψ_i

[8] Alston et al. (2000) explain how Brazilian land policies create incentives for both landowners and squatters to clear rainforests for pasture. They find that land reform programs have been responsible for 30 percent of deforestation, or approximately 15 million hectares, between 1964 and 1997.

[9] Deacon (1994) identifies cronyism and the inability of governments to enforce property rights as the two main factors feeding political uncertainty, which in turn deteriorates the profitability of long term investments. Bohn and Deacon (2000) provide evidence that political instability decreases investment share of total output, thus implying a reduction in forest capital as well.

[10] The goal of the land reforms in countries like Brazil, Bolivia, and Colombia has been to realign the highly skewed distribution of wealth (Deininger and Binswanger 1999). In many cases, land reform policies are designed so as to penalize owners who keep their land "underdeveloped" (De Janvry 1981).

with higher values meaning more effort. Probability of staying in power, p, depends on the regime's type and on the level of effort. This is captured by a strictly concave function $p_i(\psi_i)$ that has the following properties: $p'(\psi_i) > 0$ and $p''(\psi_i) < 0$, $p(0) = 0$, and $p = 1$ as $\psi_i \to \infty$. Exacting effort is costly for the regime and the cost is captured by a strictly convex function $c_i(\psi_i)$, with conditions $c'(\psi_i) > 0$ and $c''(\psi_i) > 0$ holding. Regime i solves the following maximization problem:

$$\max_{\psi_i} \{p_i(\psi_i) B - c_i(\psi_i)\} \tag{1}$$

where B denotes the benefit of staying in power and the regime receives zero payoff with probability $1 - p_i$. The first-order condition

$$p_i'(\psi_i) B - c_i'(\psi_i) = 0$$

yields the optimal level of effort $\psi_i^* = \psi_i^*(B)$. Probability of staying in power is then $p_i^* = p_i\left(\psi_i^*\right)$ which is increasing in B.[11]

For simplicity, suppose that there are two regime types: democracy ($i = 1$) and autocracy ($i = 2$). Transition matrix P summarizes the transition probabilities between the two regime states and a typical element p_{ij} denotes the probability of transitioning from regime i to regime j. Each row sums to one. Using the optimal probabilities p_i^*, the transitioning matrix becomes

$$P = \begin{bmatrix} p_{11}^* & 1 - p_{11}^* \\ 1 - p_{22}^* & p_{22}^* \end{bmatrix} \tag{2}$$

where p_{11}^* and p_{22}^* denote the probabilities of staying as a democracy and an autocracy, respectively.

Let L_f and L_a denote a country's forest area and agricultural land area respectively. By normalizing the total land endowment to one, we can write forest area as $L_f = 1 - L_a$. Agriculture and forests yield land rents given by strictly concave functions $R_a = R_a(L_a, \psi_i)$ and $R_f = R_f\left(L_f\right)$, respectively. Notice that since land allocation effectively depends on the relative land rents from the two uses, we let only agricultural land rents to be regime dependent and potentially increasing in regime's effort.[12] Regimes may influence relative land rents through direct subsidies, infrastructure projects, confiscation risk and other settlement policies. Conversion of land from forestry to agriculture yields timber benefits, sh, where s denotes value of timber per hectare and h denotes hectares converted. Land conversion cost is given by a strictly convex cost function $k(h)$ with properties $k'(h) > 0$ and $k''(h) > 0$. Total monetary benefits from a country's land endowment at time t are

$$R(L_a, h, \psi_i) = sh - k(h) + R_f(1 - L_a) + R_a(L_a, \psi_i) \tag{3}$$

There are two state variables: L_a and ψ. The agricultural land transition equation is

$$g(L_a, h) = L_a + h \tag{4}$$

[11] It is also possible that higher benefits attract more competition for power and thus the likelihood of regime change may actually increase. We could model this feature by making the cost of exacting effort to depend on variable B with higher benefits increasing the cost of effort. The interpretation would be that higher benefits translate to fiercer competition as the quality and number of political opponents increases, and thus increases the cost of effort.

[12] More precisely, regime effort influences the relative land rents from both agriculture and forests. Therefore, we could in principle have the effort variable entering both the agricultural rent and the forest rent functions. The current notation simplifies the interpretation of the results.

Equation (4) means that the agricultural land expansion occurs at the expense of forests.[13] The state transition equation also allows for the possibility of reforestation. We need to then think of timber price s and the conversion cost as denoting the cost of planting and silviculture.

The economy's dynamic problem is to allocate land to its most profitable use.[14] Using the transition matrix P the dynamic land conversion problem can be written as a Bellman equation

$$V(L_a, \psi_i) = \max_h \left\{ R(L_a, h, \psi_i) + \beta \sum_j p_{ij} \left[V\left(g(L_a, h), \psi_j\right) \right] \right\} \tag{5}$$

where $\beta = 1/(1+r)$ denotes discount factor and$r$ is the discount rate. Given a political regime i, the Euler equation characterizing the optimal path of forest conversion is

$$s + \beta E_i \left[k'\left(h^+\right) \right] + \beta E_i \left[R'_a\left(g(L_a, h), \psi\right) \right] = \beta s + k'(h) + \beta R'_f (1 - g(L_a, h)) \tag{6}$$

See "Appendix 1" for derivation. The subscript in the expectation operator E_i means that the expectations are conditional on being in regime state i, and h^+ denotes the optimal land conversion in the next period. The left-hand side (LHS) of (6) summarizes the marginal benefit of forest conversion, whereas the right-hand side (RHS) summarizes the marginal cost of conversion. Both sides are in present value terms.

Equation (6) states that the economy proceeds with land conversion in each period until the expected marginal benefits equal the marginal costs. Marginal benefit of conversion is the sum of the unit price of timber and the discounted expected marginal benefit of having new agricultural land in the next period. The second term on the LHS stands for the expected cost saving of not having to incur conversion costs in the next period and the third term stands for the expected marginal agricultural land rents. The RHS is the sum of discounted marginal timber revenue, marginal harvest cost, and discounted marginal rent from forest land. Notice that the regime effort influences only the marginal benefits from land conversion. When there is a high probability of a regime change to a new regime that is prepared to improve the relative profitability of agriculture directly through subsidies or indirectly through higher confiscation risk on unused land, the marginal benefit of land conversion becomes higher, and as a result, there will be more deforestation occurring. Similarly, if there already is a regime in power that favors agriculture, the marginal benefits from land conversion are higher. The direction of change in relative land rents is in general ambiguous and we leave this to be determined in our empirical section.

Our econometric model is closely connected to the above analytical model, and Eq. (6) also forms the basis for interpreting the empirical results. To make this connection, first notice

[13] This assumption undoubtedly simplifies the complex and region specific process of deforestation, but we can justify it on two grounds. First, it enables us to focus on our main argument that new regimes have a more active stance vis-à-vis land reforms, which in turn has an impact on the expansion of agricultural frontier in the tropics. Secondly, our specification does allow our goal of capturing the impact of political regime across different countries with varying land-uses, such as intensive agriculture, shifting cultivation, cattle ranching, plantation forestry, and timber concessions, while controlling for those variables known to be important to deforestation from previous work. Plantation forests are not necessarily a substitute for native forests or even for degraded forest stands. The real definition of deforestation is therefore more nuanced and contested than the one we apply here. Notice, however, that our main goal is to assess the impact of new regimes on agricultural expansion.

[14] This is a common assumption made in the economic analysis of land-use decisions. The same approach has been used extensively in the past work on tropical deforestation (e.g. Mendelsohn 1994; Deacon 1994; Chomitz and Gray 1996; Angelsen and Kaimowitz 1999; Pfaff 1999; Angelsen 2007; Amacher et al. 2008, 2009).

that the solution satisfying Eq. (6) is a state dependent policy function $h_i^* = h\,(L_a, \psi_i)$. The state dependent transition equation then becomes

$$g_i\left(L_a, h_i^*\right) = L_a + h_i^*$$

Dividing by land area we get

$$\frac{g_i\left(L_a, h_i^*\right)}{L_a} = 1 + \frac{h_i^*}{L_a} \tag{7}$$

Explaining changes in Eq. (7) forms the basis of our econometric model.

3 Econometric Model

Define the percentage change in agricultural area L_a in country k at time t as

$$a_{k,t} = \frac{g_i\left(L_a, h_i^*, \psi_j\right)}{L_a} - 1 \tag{8}$$

To estimate the effects of different political regime on $a_{k,t}$, we postulate the following dynamic model:

$$a_{k,t} = \beta_0 + \gamma a_{k,t-1} + \boldsymbol{\psi}_{kt}'\boldsymbol{\beta}_1 + \boldsymbol{x}_{k,t-1}'\boldsymbol{\beta}_2 + \eta_{kt} \tag{9}$$

where $k = 1, \ldots, N$ and $t = 1, \ldots, T$. Vector $\boldsymbol{\psi}_{kt}$ contains the set of indicator variables that encode the political state of country i at time t and capture the effects of regime effort. We describe how we have constructed these indicators in more detail in the following section. Vector $\boldsymbol{x}_{k,t-1}$ contains the set of predetermined control variables including proxies for those theoretical variables that are unavailable. Control variables include, for example, the level of national income as measured by GDP and its square.[15] Data on roads is unfortunately scant and would not enable to construct a large enough sample that is required for consistent estimation.[16] Our dynamic panel, however, captures the persistent effects of road building and other important factors on the expansion of agricultural margin. The full set of control variables is described in the data section.

The term η_{it} is the stochastic component of our model. It captures unobservable time-specific and country-specific effects as well as other purely random fluctuations coming from outside the model (e.g., measurement errors). The assumptions made about the stochastic term also determine the best estimation strategy. The stochastic term takes the following general form:

$$\eta_{it} = \alpha_i + \omega_t + \varepsilon_{it} \tag{10}$$

Following the standard approach in panel data analysis, we allow for both unobservable individual effects, α_i, and unobservable time-wise effects, ω_t. The individual effects may exhibit correlation with the independent variables in Eq. (9), i.e. a fixed effects model (FE),

[15] This allows us to test for the Environmental Kuznets Curve hypothesis, the presence of a turning point for deforestation-income relationship.

[16] López and Galinato (2005a, b) and Galinato and Galinato (2011) postulate a structural model where road building and crop area, the direct causes of deforestation, are simultaneously determined. They then estimate the contribution of each indirect source of deforestation to the direct causes. The focus of our study is to determine the effect of a regime change on agricultural land expansion and this effect can be through road building, subsidies, or confiscation risk.

or alternatively, they can be viewed as random draws from an i.i.d. distribution with zero mean and common variance, i.e., a random effects model (RE). FE model is preferred in country level settings such as ours, but this hypothesis is testable.[17]

A dynamic FE model with a lagged dependent variable yields inconsistent parameter estimates when using a within or first-difference (FD) estimator. This inconsistency, however, disappears in the case of a within estimator as $T \to \infty$ (Nickell 1981). Alternatively, one can use an instrumental variable method proposed by Anderson and Hsiao (1982), or a GMM-estimator proposed by Arellano and Bond (1991). Both of these methods, however, rely on FD transformation. This is not innocuous in the context of our study since we use constant binary variables to capture the effect of a regime change on the agricultural margin. Laporte and Windmeijer (2005) show that in cases like these, FD estimator performs poorly if the actual treatment effect is not constant in time. Within estimator, on the other hand, tends to be considerably more robust to this type of specification error. Hence, we use a within estimator and rely on T asymptotics.

4 Data

We follow Barbier (2001) and use country level data on annual changes in agricultural area as the dependent variable.[18] Reliability of such data is always a concern, and ideally, we would like to use observations based on more accurate methods such as remote sensing. This is not, however, feasible in the context of our study since to achieve consistent estimates requires a large sample of countries observed over a long time period. Our data come from the following sources: the World Bank's WDI and WGI databases, Penn Tables, and the Polity IV Project (2002). Tropical countries are defined as the countries that have the majority of their land mass located between the tropics (Barbier and Burgess 1997; Barbier 2001, 2004). Our final sample is an unbalanced panel dataset including 66 countries and spanning years from 1961 to 2008.[19] Table 1 provides variable descriptions and Table 2 presents sample descriptive statistics.

Two shortcomings with our dataset are the lack of price and wage data. These are some of the main components implied by our theory model as well.[20] This information is unfortunately scant, or in many cases, nonexistent. Assuming global timber and agricultural prices we are, however, able to capture their effects through time specific error component that is common to all countries at time t. Variables for cereal yield and agricultural export share also serve as good proxies to the value of agricultural products in different countries. Level of real GDP and GDP growth rate on the other hand provide good proxies for changes in real wages. In order to control for institutional differences, we include a corruption index variable in our dataset. Corruption is frequently found to be an important explanation for unsustainable forest management (e.g. Ferreira and Vincent 2010). The index scores countries on a scale between −2.5 and 2.5, where smaller values mean higher level of perceived corruption. We

[17] The advantage of fixed effects model is that we are able to control for unobserved individual effects that may bias coefficient estimates in cross-sectional studies if they are correlated with independent variables.

[18] We have removed observations with zero values. To check for potential selection problem, we estimate a Heckman selection model and cannot reject random selection. We have also removed observations that have exceptionally large values (the lower and upper 1st percentiles).

[19] See "Appendix 2" for the list of countries.

[20] Information on road building is also an important missing element (López and Galinato 2005a). Data on roads is again limited and would not allow construction of a large enough sample.

Table 1 Variable definitions

Dependent variable	Percentage change in agricultural area from last year's value. Agricultural land is defined as the land area that is arable, under permanent crops, and under permanent pastures (WDI, FAO)
Control variables	Cereal yield (kg/ha)
	Agricultural export share of total merchandise exports (%)
	GDP per capita (constant 2,000 US$)
	GDP growth (% annual change)
	Exchange rate to US$
	Total population
	Corruption index variable, time averaged over period 1996–2007 (World Bank WGI)
Regime variables	New democratic regime (first 5 years, or if interrupted during that period, then the years prior to the interruption)
	New autocratic regime (first 5 years, or if interrupted during that period, then the years prior to the interruption)
	Established democracy (subsequent years or until a new interruption)
	Established autocracy (subsequent years or until a new regime interruption)
	Preceding 2 years prior to a democratic regime change
	Preceding 2 years prior to a autocratic regime change

use a time-averaged index value for each country and then interact this average index with other control variables of interest (Galinato and Galinato 2011).[21]

Next we describe the set of political regime variables that are new to our empirical approach. Using Rodrik and Wacziarg (2005) we have recreated their set of indicators that serve to identify a change in each country's political regime. They use information reported by the Polity IV Project (2002) to encode political regime transitions, whereas we use a newer version (2009) of the same source. Dummy variables "new democratic regime" and "new autocratic regime" take on values 1 starting from the year of a major regime change depending, of course, on the direction of the change. Note that the definition of a major regime change is given by the Polity IV Project (Marshall et al. 2010). These dummy variables continue having value 1 for the subsequent 5 years unless the regime is disrupted during that period. If the new regime survives the first 5 years, then the dummy variables "established democratic regime" and "established autocratic regime" take on values 1 thereafter until they are possibly again disrupted by a new major regime change. We also augment the original set of dummy variables in Rodrik and Wacziarg (2005) to include two indicator variables that capture the preceding 2 years prior to a democratic and autocratic regime change, recognizing that there may be some preemptive policy shifts before a new regime formally takes over.[22]

[21] Ferreira and Vincent (2010) use Political Risk Services' governance indices that cover years 1984–2006 to estimate the effect of governance on timber harvests. The within variation of such index measures is small, and considering the ordinal nature of such variables together with the short time span covered, we choose time-averaged values instead. It is of course possible that the institutional conditions have developed in a given country and that these developments in turn get confounded with our political regime effects. On the other hand, political regime changes may provide impetus for institutional improvements or deterioration. These effects may therefore be hard to identify jointly with available data.

[22] We assume here that the preceding 2 years are enough to capture the expectations of a regime change and any uncertainty caused by a prospective land reform.

Table 2 Descriptive statistics: sample means and standard deviations

Variables	All countries	Africa	Latin America	Asia
Annual change in agricultural land (%)	0.541	0.411	0.568	0.918
	(1.811)	(1.250)	(2.273)	(2.376)
GDP per capita/1,000 (constant 2,000 US$)	1.231	0.640	2.480	0.941
	(1.434)	(0.966)	(1.612)	(0.830)
GDP growth (% annual change)	3.948	3.712	3.724	5.143
	(6.333)	(7.535)	(4.532)	(4.217)
Exchange rate to US$/1,000	0.482	0.555	0.061	0.960
	(7.622)	(10.027)	(0.289)	(2.913)
Total population (in 10 millions)	2.536	0.980	1.639	9.594
	(9.382)	(1.615)	(3.252)	(21.579)
Cereal yield (kg/ha)	1.523	1.045	1.954	2.348
	(0.938)	(0.704)	(0.826)	(0.849)
Agricultural export share (% of merchandise exports)	0.108	0.150	0.045	0.135
	(0.157)	(0.197)	(0.065)	(0.138)
Average corruption index	−0.622	−0.736	−0.393	−0.620
	(0.537)	(0.546)	(0.479)	(0.476)
New democratic regime (first 5 years dummy variable)	0.085	0.081	0.100	0.072
	(0.279)	(0.273)	(0.301)	(0.259)
Established democracy (subsequent years dummy variable)	0.113	0.053	0.244	0.099
	(0.317)	(0.224)	(0.430)	(0.298)
New autocratic regime (first 5 years dummy variable)	0.058	0.068	0.050	0.042
	(0.235)	(0.252)	(0.217)	(0.200)
Established autocracy (subsequent years dummy variable)	0.141	0.186	0.054	0.139
	(0.348)	(0.389)	(0.226)	(0.346)
Preceding years to democracy (prior 2 years)	0.037	0.036	0.041	0.033
	(0.189)	(0.186)	(0.199)	(0.180)
Preceding years to autocracy (prior 2 years)	0.026	0.027	0.023	0.028
	(0.159)	(0.161)	(0.149)	(0.166)

This complete set of indicators enables us to investigate the impact of different phases of a new political regime in more detail. For example, the average life-span of a military regime is 5 years (Brooker 2009). These types of regimes are usually concentrated on getting a few specific objectives completed before stepping down. It is interesting therefore to see whether the first years of a new regime have distinct impact on the expansion rate of agriculture as the level of uncertainty on land rents might be at its highest. Notice that the baseline case here is "no regime changes of any kind" during the sample period. Thus the dummy variables capture the effect of a regime change compared to status quo, whether that is a democratic or autocratic regime. Also, it is important to note that transitions from one regime to another are not clear cut or instantaneous necessarily which somewhat complicates the identification of the year of a regime change.[23]

[23] For example, a revolution could sweep in during 1 year or it could require a prolonged civil war before any clear outcome is perceivable. In many cases, the outcome is actually muddled where the new regime

5 Results and Discussion

Table 3 reports estimation results using a model that includes lagged dependent variable, our set of political regime variables, fixed country-specific and fixed time-specific effects, that is, we first estimate model (9) using restriction $\boldsymbol{\beta}_2 = 0$. We also include region-wise interaction terms between the regime variables $\boldsymbol{\psi}$ and Africa and Asia to capture potential differences in effects between the main regions. To save space, the second and the third columns report these interaction terms, whereas the first column reports the estimates for Latin America as the baseline. Cluster robust standard errors are reported below the coefficient estimates.[24] The estimation results show that new democratic regimes have had a positive and statistically significant effect on the rate of agricultural land expansion, and this effect is not significantly different between the regions.[25] The effect is also quantitatively significant which can be seen from comparing it to the average expansion rates in Table 2. New autocratic regimes have similarly had a positive and statistically significant effect, except now the interaction term for Africa is negative and statistically significant. This means that the effect in Africa has been smaller, and when comparing the magnitudes of the coefficient estimates, the negative coefficient almost totally cancels out the positive effect. Established democracies have had a positive and statistically significant effect only in Africa. Established autocracies have had a positive effect in Latin America and Asia, but as was the case with new autocratic regimes the interaction term for Africa nearly cancels out the positive effect. The coefficient on preceding years to autocracy also highlights differences between regions. The lagged dependent variable is statistically significant but the coefficient is small, implying low persistence.[26] We discuss the interpretations of these results collectively after representing the estimation results that include the set of predetermined variables.

Table 4 reports results using the unrestricted specification in (9). Again, all region-wise interaction terms are reported in the second and the third column to save space. As before, we have interaction terms between the political regime variables and the region variables. We also include interaction terms between GDP and the region variables, and between GDP and corruption index and its interactions with the region variables.[27] Corruption index itself is assumed to be time-invariant and therefore included in the country-specific effects. The interaction term between corruption and GDP captures the influence of institutional differences on the effect of income on deforestation. The coefficient estimates in the first column again report the results for Latin America as the baseline. Notice that our final specification does not include squared GDP term as it was deemed statistically insignificant. The number of observations is also considerably smaller than in Table 3 due to data availability. Table 5 estimates a model without agricultural export share variable since the number of observations on that variable was considerably smaller and since it is not a significant predictor in Table 4. The results with respect to regime variable remain unchanged.

The effects of regime changes on deforestation are again region dependent. Starting with new democratic regime variable, it is positive and statistically significant for Latin America

Footnote 23 continued
lies somewhere in between the two regime types. In encoding the indicator variables, we have followed the definitions provided by Polity IV in a consistent manner in order reduce ambiguities.

[24] Cluster robust standard errors allow for both within heterogeneity and serial correlation.

[25] We use a Wald test to determine whether differences in slopes are significant.

[26] Dynamic IV and GMM estimates for the lagged dependent variable did not differ much from the within estimate.

[27] We also tried including interaction terms with other control variables but these were deemed as not important.

Table 3 Two-way fixed effects model, cluster robust standard errors[a] [regime variables only ($X = 0$, N = 3,433)]

		Regional interaction terms: Africa	Regional interaction terms: Asia
Dependent variable: Annual percentage change in agricultural land			
Explanatory variables			
Lagged dependent variable	0.202***		
	(0.039)		
New democratic regime (first 5 years)	0.579**	−0.117	0.136
	(0.282)	(0.301)	(0.568)
Established democracy (subsequent years)	0.100	0.625**	−0.274
	(0.215)	(0.266)	(0.522)
New autocratic regime (first 5 years)	0.801***	−0.770***	−0.220
	(0.187)	(0.217)	(0.427)
Established autocracy (subsequent years)	0.792***	−0.749***	0.139
	(0.268)	(0.276)	(0.373)
Preceding years to autocracy (prior 2 years)	1.267**	−1.450**	−1.103
	(0.574)	(0.598)	(0.698)
Preceding years to democracy (prior 2 years)	0.063	−0.159	1.054
	(0.173)	(0.216)	(1.054)
Within R^2	0.08		
Breusch Pagan LM test[b]	256.21***		
Wald test ($\psi = 0$)	16.12***		

Significance levels: * 0.1; ** 0.05; *** 0.01
[a] The interaction terms are in separate columns to reduce the length of the table
[b] Lagged dependent variable not included

and not statistically different for Africa. In Asia, however, the effect of new democracy is now considerably smaller and even of opposite sign. Established democracy variable is now statistically not different from zero, implying that once a democratic regime has survived the first 5 years, it has no clear tendency to increase or slow down the expansion of agriculture. New autocratic regime variable is significant and positive for Latin America but negative for Africa. This also means that in Africa, new autocracies have not had quantitatively a significant effect on agricultural land expansion. Established autocracy variable has the same pattern. The preceding years to autocracy variable has a positive and statistically significant effect on the dependent variable in Latin America, but in Asia and Africa, this effect is considerably smaller or even of opposite sign for Africa. Preceding years to democracy have had a negative and significant effect in Africa.

The lagged dependent variable is again statistically significant but the coefficient is now smaller than in Table 3. GDP growth rate has no significant effect on the dependent variable, whereas weaker exchange rate of the local currency relative to US dollar has a positive and statistically significant effect on the dependent variable. Population has a positive effect and cereal yield has a negative effect on the rate of expansion of agricultural land. Agricultural export share has no effect. In Table 4, the coefficient for GDP per capita is negative and significant in the case of Latin America, but the interaction term with Africa is positive and significant. This means that higher income level has reduced or reversed agricultural

Table 4 Two-way fixed effects model, cluster robust standard errors ($N = 1{,}947$)

		Regional interaction terms: Africa	Regional interaction terms: Asia
Dependent variable: Annual percentage change in agricultural land			
Explanatory variables			
Lagged dependent variable	0.149***		
	(0.055)		
Lagged GDP growth (%)	−0.002		
	(0.009)		
Lagged exchange rate to US$/1,000	0.208***		
	(0.066)		
Lagged population (in 10 millions)	0.017**		
	(0.007)		
Lagged cereal yield/1,000	−0.263*		
	(0.134)		
Lagged agricultural export share/100	−0.093		
	(0.481)		
Lagged GDP per capita/1,000	−0.444*	0.607**	−0.397
	(0.225)	(0.268)	(0.275)
Lagged GDP × corruption	−0.500	0.889*	1.628**
	(0.435)	(0.476)	(0.779)
New democratic regime (first 5 years)	0.848**	−0.526	−0.934*
	(0.358)	(0.387)	(0.470)
Established democracy (subsequent years)	0.366	0.342	−0.545
	(0.245)	(0.341)	(0.469)
New autocratic regime (first 5 years)	1.012***	−0.940***	−0.387
	(0.215)	(0.259)	(0.378)
Established autocracy (subsequent years)	1.073***	−0.902***	0.217
	(0.248)	(0.284)	(0.469)
Preceding years to autocracy (prior 2 years)	1.549**	−1.669**	−1.230*
	(0.645)	(0.677)	(0.731)
Preceding years to democracy (prior 2 years)	0.292	−0.668**	−0.269
	(0.180)	(0.259)	(0.323)
Within R^2	0.13		
Breusch Pagan LM test[a]	85.54***		
Wald test ($X = 0, \psi = 0$)	31.06***		

[a] Lagged dependent variable not included

expansion in Latin America, whereas in Africa the opposite holds. For Asian countries, the coefficient estimate is not significantly different from Latin America. Also the corruption interaction term has differing effects across regions. In Latin America, better control of corruption has no statistically significant influence on the effect of GDP on the rate of agricultural land expansion. In Africa and Asia, however, there is positive and statistically significant influence. In these two regions, higher income levels result in higher rates of agricultural expansion when the control of corruption is also improving.

Table 5 Two-way fixed effects model, cluster robust standard errors (no export share variable, $N = 2{,}823$)

		Regional interaction terms: Africa	Regional interaction terms: Asia
Dependent variable: Annual percentage change in agricultural land			
Explanatory variables			
Lagged dependent variable	0.169***		
	(0.048)		
Lagged GDP growth (%)	0.005		
	(0.005)		
Lagged exchange rate to US$/1,000	0.210***		
	(0.026)		
Lagged population (in 10 millions)	0.013*		
	(0.006)		
Lagged cereal yield/1,000	−0.223**		
	(0.086)		
Lagged GDP per capita/1,000	−0.349	0.340	−0.277
	(0.250)	(0.245)	(0.362)
Lagged GDP × corruption	−0.485	0.566	1.271
	(0.491)	(0.500)	(0.937)
New democratic regime (first 5 years)	0.776**	−0.443	−0.771**
	(0.312)	(0.332)	(0.352)
Established democracy (subsequent years)	0.314	0.290	−0.687
	(0.225)	(0.310)	(0.448)
New autocratic regime (first 5 years)	0.844***	−0.734***	−0.256
	(0.180)	(0.202)	(0.343)
Established autocracy (subsequent years)	0.771***	−0.692***	0.355
	(0.248)	(0.260)	(0.389)
Preceding years to autocracy (prior 2 years)	1.442**	−1.581**	−1.237*
	(0.614)	(0.646)	(0.690)
Preceding years to democracy (prior 2 years)	0.221	−0.440*	−0.299
	(0.180)	(0.224)	(0.279)
Within R^2	0.11		
Breusch Pagan LM test[a]	136.67***		
Wald test ($X = 0, \psi = 0$)	68.82***		

[a] Lagged dependent variable not included

There are some clear interpretations for our collective results with respect to the regime variables. Starting with Latin America, the effects of new regimes, democratic and autocratic, have been positive and quantitatively significant. It is well known that this region has witnessed multiple attempts to reform landownership during our sample period, and in some countries, like Mexico, the drive to reform was initiated even earlier (De Janvry 1981; Deininger 2003). Powerful landlord classes have historically controlled vast tracts of land in many of these countries, and the inequality of ownership has been high. Large estates called "haciendas" and owned by landlords have continued to play a significant role in the political and socio-economic setting (Brockett 1990). This explains why ownership of land

still continues to be a controversial issue and also the cause of land reform and settlement policies under both new autocratic and new democratic regimes. In terms of our theory model, both regime types in Latin America have encouraged the expansion of agriculture at the expense of forests by influencing the relative land rents, directly or indirectly, with the goal of consolidating their power. These results are also supported by empirical findings in Barbier (2001).[28] New regimes have a more active stance towards land use policies exactly because land ownership has been and continues to be at the core of the social and economic issues causing political instability. Established autocracies have also had a clear positive effect on the expansion of agriculture. One possible explanation is that new autocracies, once established, continue to rely on redistributive policies in order to stay in power (De Janvry 1981). This would further translate into weakening property rights and encourage conversion of tropical forests to agriculture. Finally, preceding years to autocracy have also had an accelerating effect on expansion of agricultural land which may imply pre-existing social rift.

The regime variable estimates for countries in Africa seem to generally differ from those of Latin America. In the case of new democratic regime variable, there is, however, no statistically significant difference in the coefficient estimate when compared to Latin American countries. This implies that, like in Latin America, new democracies in Africa have tended to accelerate the expansion of agricultural land. New and established autocracies, on the other hand, have quantitatively much smaller effect on the rate of deforestation than in Latin America. Referring to Table 2, the descriptive statistics show that new autocracies in Africa have been relatively more long-lived than elsewhere. This could imply that the leaders of these autocratic regimes have been less worried about being overthrown and thus less inclined to embark on reformist policies. They might also be more reliant on rents from other types of natural resources such as oil and minerals (Jensen and Wantchekon 2004).[29] This could mean that land is not as important source of power and a form of redistribution as it is in Latin America.[30] In Table 3, established democracies have a positive effect on the rate of deforestation, but this effect becomes statistically insignificant once we add predetermined variables. Finally, our results showing that agricultural expansion is reduced during the 2 years prior to a new democratic regime and new autocratic regime may capture the effect of prolonged civil wars and chaos.

For the most part, the regime variable estimates for Asian countries are similar to those of Latin America. The exception is the new democratic regime variable in Table 4 that has a negative sign. This means that new democratic regimes have not accelerated agricultural expansion in Asia; they may have even reduced it. New and established autocracy variables have the same sign as in Latin America. There are some anecdotal examples of authoritarian leaders who have used redistribution of land as a political weapon in Asia. For example, Ferdinand Marcos, the authoritarian leader of Philippines from 1965 to 1986, redistributed

[28] Barbier (2001) finds that a general political stability indicator variable is a significant and positive predictor of agricultural land expansion in Latin America. Our interpretation goes further in showing that political regime is important, and as such the results for Latin American countries are best in line with our initial predictions.

[29] This interpretation is in line with the literature on rent-seeking elites and resource curse which tend to invite civil war and armed conflict especially in resource rich countries (Ross 1999; Addison et al. 2002). In terms of our theory model, new regimes exert effort to stay in power through war and factional fighting, and also through distributing resource rents to their supporters.

[30] Furthermore, traditional forms of land ownership, such as community lands and forests, have persisted in the face of attempts to reform land titling systems (Platteau 2000). They continue to be a prevalent form of de facto land use right even though community lands may still lack a judicial recognition.

private land to small farmers under his program "Operation Land Transfer."[31] These similarities between Asian and Latin American countries, on the one hand, and differences between them and African countries, on the other, are perhaps best explained by their respective institutions of land ownership. In many Asian countries, similar to the experiences in Latin America, landlord classes have historically controlled large tracts of land, which have then been cultivated through tenancy and sharecropping arrangements. Such institutions have been less common in Africa (Daley and Hobley 2005).

6 Conclusions

We began our analysis by proposing a simple land allocation model that allows for regime dependent confiscation risk and agricultural subsidy policy. The theory model forms the basis for our empirical model which we estimate and test for the presence of regime effects on deforestation. We find that in Latin America and Africa, new democratic regimes have accelerated the expansion of agricultural land and thus tropical deforestation, whereas in Asia they have had the opposing effect. New autocratic regimes have had a positive effect on the rate of deforestation, but this effect has been relatively smaller in Africa. Our results show that those autocratic regimes that have survived the first 5 years have a tendency to further accelerate agricultural land expansion in both Latin America and Asia. In Africa, this effect has again been considerably smaller. Finally, we find that established democracies have had no statistically significant effect on tropical deforestation. In terms of our theory model, new regimes have had a tendency to exert effort to stay in power which has in turn translated to higher rate of agricultural land expansion and therefore to increasing risk of deforestation in the tropics.

Bohn and Deacon (2000) conclude their work with an optimistic note. They deem that the recent "trend toward democracy and reduced political instability worldwide" provides a good prospect for the future of global forests. The main findings of our paper are not as optimistic, at least with respect to tropical forests in some regions. Once we include new politically constructed data on regime implementation and persistence and success, we find that democratization should not be viewed automatically as a panacea that leads to reduced pressures on the exploitation of tropical forest resources. New democratic regimes may simply favor the socio-economic and political stability implications of wider access to agricultural land over the other land use alternatives (Midlarsky 1998). Established democracies, on the other hand, have not been able to reduce deforestation pressures. Barbier (2011) further notes that the demand for new agricultural land in Latin America, Africa and Asia is unlikely to be reduced. He projects that, within the next 40 years, over one-fifth of the expansion in crop production will rely on the creation of new cultivated land area rather than on more intensive use of existing agricultural area, and that two thirds of the expansion area will come at the expense of primary forests. Brooker (2009) on the other hand predicts that the twenty-first century will witness its share of regime changes, both democratic and non-democratic. The future of the remaining world tropical forests will most likely remain uncertain according to our results, and it will crucially depend on the relative economic values of alternative land uses, but also, without a doubt, on the political pressures to guarantee wider access to cultivated land among the populace.

[31] This policy is cited as responsible for gaining wide support of the population for the ruling regime. Land expropriations, however, targeted mainly Marcos's political enemies such as the communist movement (Borras Jr. 2001).

Appendix 1

The Bellman equation is

$$V\left(L_a, \psi_i\right) = \max_h \left\{ R\left(L_a, h, \psi_i\right) + \beta \sum_j p_{ij} \left[V\left(g\left(L_a, h\right), \psi_j\right)\right] \right\} \tag{11}$$

The first-order condition in regime i is

$$s - k'\left(h\right) + \beta \left[p_{ii} V_1\left(g\left(L_a, h\right), \psi_i\right) + p_{ij} V_1\left(g\left(L_a, h\right), \psi_j\right)\right] \tag{12}$$

where V_1 denotes the derivative of the value function with respect to the first argument. By Envelope theorem:

$$\begin{aligned} V_1\left(L_a, \psi_i\right) = & -R'_f\left(1 - L_a\right) + R'_a\left(L_a, \psi_i\right) + \beta \left[p_{ii} V_1\left(g\left(L_a, h\right), \psi_i\right)\right. \\ & \left. + p_{ij} V_1\left(g\left(L_a, h\right), \psi_j\right)\right] \end{aligned}$$

Combining the above two, we get

$$s - k'\left(h\right) + V_1\left(L_a, \psi_i\right) + R'_f\left(1 - L_a\right) - R'_a\left(L_a, \psi_i\right) = 0$$

Forwarding this by one period for regime state i

$$s - k'\left(h_i^+\right) + V_1\left(g\left(L_a, h\right), \psi_i\right) + R'_f\left(1 - g\left(L_a, h\right)\right) - R'_a\left(g\left(L_a, h\right), \psi_i\right) = 0$$

and for regime state j

$$s - k'\left(h_j^+\right) + V_1\left(g\left(L_a, h\right), \psi_j\right) + R'_f\left(1 - g\left(L_a, h\right)\right) - R'_a\left(g\left(L_a, h\right), \psi_j\right) = 0$$

Rearranging:

$$\begin{aligned} V_1\left(g\left(L_a, h\right), \psi_i\right) &= k'\left(h_i^+\right) + R'_a\left(g\left(L_a, h\right), \psi_i\right) - s - R'_f\left(1 - g\left(L_a, h\right)\right) \\ V_1\left(g\left(L_a, h\right), \psi_j\right) &= k'\left(h_j^+\right) + R'_a\left(g\left(L_a, h\right), \psi_j\right) - s - R'_f\left(1 - g\left(L_a, h\right)\right) \end{aligned}$$

Substitute these back to the original FOC:

$$\begin{aligned} & s - k'\left(h\right) + \beta p_{ii} \left[k'\left(h_i^+\right) + R'_a\left(g\left(L_a, h\right), \psi_i\right) - s - R'_f\left(1 - g\left(L_a, h\right)\right)\right] \\ & + \beta p_{ij} \left[k'\left(h_j^+\right) + R'_a\left(g\left(L_a, h\right), \psi_j\right) - s - R'_f\left(1 - g\left(L_a, h\right)\right)\right] = 0 \end{aligned}$$

Rearranging:

$$\begin{aligned} & \left(1 - \beta p_{ii} - \beta p_{ij}\right) s - k'\left(h\right) + \beta p_{ii} \left[k'\left(h_i^+\right) + R'_a\left(g\left(L_a, h\right), \psi_i\right)\right] \\ & + \beta p_{ij} \left[k'\left(h_j^+\right) + R'_a\left(g\left(L_a, h\right), \psi_j\right)\right] - \left(p_{ii} + p_{ij}\right) \beta R'_f\left(1 - g\left(L_a, h\right)\right) = 0 \end{aligned}$$

Noticing that $p_{ii} + p_{ij} = 1$, we get:

$$\begin{aligned} & \left(1 - \beta\right) s - k'\left(h\right) + \beta p_{ii} \left[k'\left(h_i^+\right) + R'_a\left(g\left(L_a, h\right), \psi_i\right)\right] \\ & + \beta p_{ij} \left[k'\left(h_j^+\right) + R'_a\left(g\left(L_a, h\right), \psi_j\right)\right] - \beta R'_f\left(1 - g\left(L_a, h\right)\right) = 0 \end{aligned}$$

Finally, using the expectation operator, we can simplify the above expression to yield Eq. (6):

$$\left(1 - \beta\right) s + \beta E_i \left[k'\left(h^+\right) + R'_a\left(g\left(L_a, h\right), \psi\right)\right] = k'\left(h\right) + \beta R'_f\left(1 - g\left(L_a, h\right)\right) \tag{13}$$

Appendix 2: Countries

Angola, Belize, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, Colombia, Comoros, Dem. Rep. Congo, Rep. Congo, Costa Rica, Cote d'Ivoire, Djibouti, Dominican Republic, Ecuador, El Salvador, Ethiopia, Fiji, Gabon, Gambia, Ghana, Guatemala, Guinea, Guyana, Haiti, Honduras, India, Indonesia, Jamaica, Kenya, Liberia, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mauritius, Mexico, Mozambique, Nicaragua, Niger, Nigeria, Panama, Papua New Guinea, Peru, Philippines, Rwanda, Senegal, Sierra Leone, Sri Lanka, Sudan, Tanzania, Thailand, Togo, Uganda, Venezuela, Vietnam, Rep. Yemen, Zambia, Zimbabwe.

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