Natural Resources Forum 43 (2019) 230–240 DOI: 10.1111/1477-8947.12186

Does foreign direct investment impede forest area in Sub-Saharan Africa?

Boris OK Lokonon and Ichaou Mounirou

Abstract

Foreign direct investment is an engine of economic growth. However, it may affect environmental quality (improve or deteriorate it), depending on the context. Under a multivariate framework, this paper aims to investigate the relationship between foreign direct investment and deforestation for Sub-Sahara African countries with economic growth, trade openness and urbanization as additional determinants of deforestation. The analyses reveal that all variables are non-stationary and cointegrated based on recent panel data techniques. On applying dynamic ordinary least squares, the long-run results suggest the validity of the pollution haven hypothesis for some countries, and that of the pollution halo hypothesis for other countries. The findings are also mixed across Sub-Sahara African countries for trade openness and urbanization. The results from this study suggest that Sub-Sahara African countries should continue attracting foreign direct investment, while a certain number of them should put more emphasis on controlling deforestation associated with foreign direct investment inflows to limit greenhouse gas concentrations in the atmosphere.

Keywords: Pollution haven hypothesis; deforestation; pollution halo hypothesis.

1. Introduction

The pollution haven hypothesis posits that foreign direct investment (FDI) has a positive effect on pollution. This positive relationship between FDI inflows and pollution is that pollution-intensive industries are more likely to move from developed to less developed countries due to the less stringent or weak environmental regulation in the less developed countries (Al-mulali and Tang, 2013; Neequaye and Oladi, 2015; Sapkota and Bastola, 2017; Shahbaz *et al*., 2015). Essentially, the environment is a normal good and this is why developing countries have more lax environmental regulation stringencies or fragile environmental monitoring systems and institutions than developed countries (Neequaye and Oladi, 2015). In the empirical literature, FDI inflows are also found to have a negative effect on pollution through transferring more environmentally friendly technologies from developed to less developed countries (Al-mulali and Tang, 2013); indicating the non-validity of the pollution haven hypothesis and which is referred to as the pollution halo hypothesis (Shahbaz *et al*., 2015). However, the debate surrounding the pollution haven hypothesis/the pollution hallo hypothesis is still open, though FDI is considered as an engine of economic growth (Kivyiro and Arminen, 2014). Aliyu (2005) identified three dimensions of the pollution haven hypothesis. The first is based on comparative advantage, in which developing countries relax environmental rules to attract FDI. The second is relative to the stringent environmental regulations in developed countries, which lead to hazardous wastes in developing countries through FDI. The third includes the large-scale depletion of natural resources (such as forest and petroleum) in developing countries by multinationals.

Recently, the issues related to land grabbing emerged in the economics literature (German *et al*., 2011). Land grabbing may affect forest resources. Foreign investors are taking part in commercial agriculture in developing countries, so they need more arable land for large scale agriculture, such as biofuels (German *et al*., 2011). Forests are recognized to be of paramount importance in tracking carbon from the atmosphere, since they serve as carbon sinks. Therefore, forest conservation is important for carbon sequestration and for the limitation of greenhouse gas

Boris OK Lokonon, Laboratoire d'Economie Publique (LEP), Laboratoire de Recherche en Economie et Gestion (LAREG), Faculté des Sciences Economiques et de Gestion (FASEG), Université de Parakou, Parakou, Benin. E-mail: odilonboris@gmail.com

Ichaou Mounirou, Laboratoire d'Economie Publique (LEP), Laboratoire de Recherche en Economie et Gestion (LAREG), Faculté des Sciences Economiques et de Gestion (FASEG), Université de Parakou, Parakou, Benin. E-mail: ichaou_bassir@yahoo.fr

(GHG) concentrations in the atmosphere, in addition to its other environmental attributes such as biodiversity and habitat conservation. As a result, there is an advocacy to slow down deforestation, even so to afforest as a means to limit climate change that is causing the global rise in temperature and erratic rainfall patterns, for example. It should be noted that, according to the Intergovernmental Panel on Climate Change (IPCC), anthropogenic GHG emissions are the main causes of climate change (IPCC, 2013). Consequently, all countries, even developing countries, are expected to cut down GHG emissions (mitigation strategies), though the mitigation efforts may be different with respect to the type of countries, either developed or developing. For Arcand *et al.* (2008), deforestation constitutes an issue which has largely been concentrated in developing countries. As an illustration, the yearly deforestation rate was estimated at 0.21 between 1990 and 2000 in Central Africa (Duveiller *et al.*, 2008). Numerous studies have analyzed the determinants of deforestation and/or the validity of environmental Kuznets curve (EKC) in the forest sector in developing countries. These studies include Culas (2007), Barbier (2004), van Nguyen and Azomahou (2003) and Bhattarai and Hammig (2001). Choumert *et al.* (2013) have performed a meta-analysis of the literature of the EKC studies for deforestation and concluded that the EKC story will not fade until theoretical alternatives are provided. However, there is a gap in the literature regarding the relationship between FDI and deforestation (the pollution haven hypothesis/the pollution hallo hypothesis in the forest sector) in developing countries. Note that Busa (2013) found that wealthy countries drive deforestation in poorer countries through the importation of forest resources.

The objective of this paper is, therefore, to investigate the effect of FDI inflows on deforestation in Sub-Sahara African (SSA) countries. Consequently, the present paper contributes to the literature by investigating the pollution haven hypothesis/pollution hallo hypothesis in the forest sector, as forests play an important role in the climate system. Validating the pollution haven hypothesis or the pollution halo hypothesis in the forestry sector is of paramount importance for policymakers to effectively enhance environmental quality. For Culas (2007), one of the most serious environmental problems in recent times is tropical deforestation (occurring mostly in developing countries), leading to a reduction in the supply of forest products, siltation, flooding and soil degradation. SSA is chosen for this study for two reasons. First, FDI inflows to the region have grown nearly sixfold over the past decade and the largest inflows are either in sectors in which SSA countries have a comparative advantage (e.g., natural resources such as forest and agriculture), or where there is a need for investment, and returns are high such as in construction (World Bank, 2014). Second, deforestation constitutes an issue, which has largely been concentrated in developing countries (Arcand *et al.*, 2008), that include SSA countries where many of the low human development countries are located.

The remainder of the paper is organized as follows. Section 2 presents a synthesis on the drivers of deforestation in the economics literature. Material and methods used are described in Section 3. Section 4 presents the empirical results and their discussion and Section 5 concludes the paper along with policy implications.

2. What are the drivers of deforestation?

The literature on the determinants of deforestation reveals that three main categories of factors may influence deforestation, such as demographic, economic and political factors.

2.1. Demographic factors

Different variables are used to analyze the effect of demographic factors such as population, population growth, population density, the share of the rural population in the total population and urbanization. For example, Allen and Barnes (1985) showed that an increase in the total population is associated with a reduction in forest area. In contrast, Bhattarai and Hammig (2001) found that the growth rate and density of the rural population have different effects on deforestation across groups of countries. Bhattarai and Hammig (2001) concluded that the effect of population growth is significant and negative in Latin America and Africa, but positive in Asia. Conversely, the effect of the density of the rural population is significant and negative only in Asia. Urbanization is also recognized as a determinant of deforestation (Ehrhardt-Martinez, 1998). Solarin *et al.* (2017) found a positive effect of urbanization on carbon dioxide emission in Ghana, pointing out the detrimental effect of urbanization on pollution.

2.2. Economic factors

The relationship between economic growth and deforestation can be of the form of an inverted U-shaped relationship, known as the EKC. The EKC was derived from environmental factors related either to air quality or water quality (Grossman and Krueger, 1991, 1995; Selden and Song, 1994). The EKC originated from the seminal work of Kuznets (1995) that suggested an inverted U-shape relationship between income inequality and economic growth. The results obtained for forest areas are more contrasted. Bhattarai and Hammig (2001), as well as Cropper and Griffiths (1994), found an EKC linking per capita income and deforestation rates for African and Latin American countries. Combes Motel *et al.* (2009), Culas (2007) and Bhattarai and Hammig (2001) highlighted an EKC for deforestation by emphasizing the importance of institutional factors. Moreover, Koop and Tole (1999) found no

EKC describing the relationship between per capita income and deforestation over similar periods. Van Nguyen and Azomahou (2003) even obtained a U-shaped relationship between per capita income and deforestation.

There are other economic factors likely to influence deforestation apart from economic growth such as real exchange rate, external debt, infrastructures, poverty, market conditions and international trade. Arcand *et al*. (2008) showed that a depreciation of the real exchange rate accentuates deforestation in developing countries, but attenuates it in developed countries. International trade is also the object of consideration (Busa, 2013). External debt may encourage developing countries to deforest in order to obtain foreign exchange (Bhattarai and Hammig, 2001; Rudel and Roper, 1997). Moreover, infrastructures play an important role in deforestation (Rudel and Roper, 1997). Several studies have highlighted the impact of poverty and inequality on deforestation (Alix-Garcia, 2008; Ehrhardt-Martinez, 1998). It is worth noting that the underlying factors of deforestation are more difficult to apprehend, but also more important to detect. As part of their comprehensive analysis, Geist and Lambin (2002) concluded that market conditions play a role in 81% of deforestation cases. In addition, international prices of agricultural commodities have long been known to drive deforestation. In Cameroon, the rate of deforestation observed between 1967 and 1997 was strongly correlated with macroeconomic conditions and, more particularly, with the price of cash crops such as coffee or cocoa. In Brazil, the national deforestation rate has been closely linked to soybean and livestock prices since 2000 (Geist and Lambin, 2002).

Cole (2004), using detailed data on North–South trade flows, examined the evidence for the pollution haven hypothesis, assessed the extent to which trade patterns are influencing pollution emissions, and has ascertained whether these trade patterns could be determined by divergent environmental regulations between the North and the South. The findings support the pollution haven hypothesis for air and water pollutants. He (2006) constructed a simultaneous equations model to study the FDI-emission nexus in China, using a data panel of China's 29 provinces' industrial sulfur dioxide emissions. The findings provided convincing supportive evidences for pollution haven hypothesis in China. As for Kearsley and Riddel (2010), they found little evidence that pollution havens play a significant role in shaping the EKC, testing the pollution haven hypothesis through trade (dirty exports and imports in sector k). Similarly, Solarin *et al*. (2017) investigated the pollution haven hypothesis in Ghana using carbon dioxide emission as an indicator of air pollution between 1980 and 2012. These authors used, as main determinants, gross domestic product (GDP), GDP squared, energy consumption, renewable energy consumption, fossil fuel energy consumption, FDI, institutional quality, urbanization and trade openness. They tested the pollution haven hypothesis through the relation between pollution and FDI and found the existence of this hypothesis in Ghana.

Investments in the agricultural sectors may also influence forest area. FAO (2016) showed the relationship between changes in forest cover, investments in agriculture and forests as well as poverty. In general, the loss of forest area is particularly important in low-income countries as investments in agriculture and forestry are modest. Direct public investment is increasingly focused on social and environmental protection programmes and other public goods (such as research and development), and there is a growing emphasis on the implementation of favourable conditions for private sector investment. Any incentive programme for investment should include social and environmental protection measures. McFarland *et al*. (2015) showed that, in Brazil, subsidies for rural credits to meet environmental criteria have saved US\$1.4 billion between 2008 and 2011; furthermore, without the reform, an estimated 270,000 hectares of additional forests would have been lost. Similarly, thousands of forest-dependent poor families have received financial benefits under the 'Bolsa Verde' programme and, in return, they committed to preserving vegetation cover and managing natural resources in a sustainable manner (Brazil, 2014). Fowler *et al*. (2011) showed that in low-income countries, the share of the forest sector in GDP is relatively high, but public spending on forests is low.

While forest investment strategies vary greatly in their nature and scale, there are two broad approaches, namely direct public sector investment and measures to create and strengthen a supportive environment to attract private investment to forests. Strong and sustained programmes of direct public investment have helped some countries put an end to deforestation due to the expansion of agricultural land. As illustration, China, Egypt, India, Iran, Kuwait, Mexico, Morocco and Tunisia have all launched national programmes of afforestation or forest rehabilitation (FAO, 2016). These countries have given greater political priority to forests because they expressed concern that further degradation of forests may result in higher costs in the future. Thus, many countries have succeeded in creating enabling environments for private investment in forests. New instruments and investments in financial markets have emerged; these instruments and investments enable forest owners to monetize their forest assets and increase their income, an example being the securitization of forest-backed investments (FAO, 2015a). In Costa Rica, for example, forest and financial sector actors use instruments such as microcredit, repurchase agreements or securitization of forest-based liquidity flows to improve financing for small-scale forestry (FAO, 2015b).

2.3. *Political factors*

Other studies have focused on the influence of political factors on deforestation. These studies are less numerous than those focusing on economic factors, partly because of the lack of existing data on the political and institutional factors. Studies, such as Bhattarai and Hammig (2001), Didia (1997) and Deacon (1994), pointed out that deforestation is accentuated in countries where democracy is weak and political institutions are of poor quality. Moreover, property rights and the difficulties of enforcing them in some developing countries may also be the drivers of deforestation (Angelsen and Kairnmovitz, 1999; Deacon 1999). Institutional factors are found to decrease carbon dioxide emissions in Ghana (Solarin *et al*., 2017).

Among economic factors likely to affect deforestation, there are FDI inflows. However, the relationship between FDI inflows and deforestation (pollution haven hypothesis versus pollution halo hypothesis), to the best of our knowledge, is under-studied in the economics literature. Most of the studies link FDI to pollution besides deforestation. This is why the present study focuses on the investigation of the link between FDI and deforestation taking SSA as a research area.

3. Materials and methods

3.1. Model specification

The goal of this study is to investigate the relationship between deforestation and FDI inflows in SSA countries. The modeling framework is presented as follows in its general form:

$$Deforestation_{it} = f\left(FDI_{it}, GDP_{it}, GDP_{it}^2, Openness_{it}, \text{Urbanization}_{it}\right) \quad (1)$$

where $Deforestation_{it}$ is the annual deforestation level in square kilometers; FDI_{it} refers to FDI net inflows as a percentage of GDP; GDP_{it} is per capita GDP in constant 2010 US$; $Openness_{it}$ is trade openness as a percentage of GDP; and Urbanization_{it} captures the size of the urban population. Deforestation is derived from forest area that is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems. Deforestation is computed as the annual decrease in forest area [$-(Forest\ area_t - Forest\ area_{t-1})$ with t standing for the year; the opposite of the outcome of the difference]. The choice of the explanatory variables is done following the literature on the pollution haven hypothesis and on the EKC in the forestry sector (e.g., Behera and Dash, 2017; Bhattarai and Hammig, 2001; Busa, 2013; Culas, 2007; Solarin *et al*., 2017). The current study employs deforestation as it aims to investigate the validity of the pollution haven hypothesis/pollution halo hypothesis in the forestry sector. Several researchers (such as Bhattarai and Hammig, 2001; Culas, 2007; Solarin *et al*., 2017) have used per capita real GDP to measure the level of economic growth. The square of per capita GDP is included following the seminal work of Kuznets (1955) that suggested an inverted U-shape relationship between income inequality and economic growth; and Panayotou (1993) suggested an apparent U-shaped relationship between environmental degradation and economic development, which is known as EKC found 2 years before by Grossman and Krueger (1991), using cross-sectional data for 42 countries' urban areas and three pollutants. Within this framework, deforestation is expected to increase with per capita GDP during the early stages of economic growth and then decline with per capita income after reaching a certain threshold level (Bhattarai and Hammig, 2001; Culas, 2007). Urbanization and population pressures are seen as having a positive effect on deforestation as it may stimulate demand for forest products (Behera and Dash, 2017; Bhattarai and Hammig, 2001; Culas, 2007; Solarin *et al*., 2017). The effect of trade openness on deforestation remains controversial. Trade openness may lead to deforestation as developed countries drive deforestation into developing countries through imports of forest resources (Busa, 2013).

Prior to the detection of the order of integration of the variables, it is necessary to test for cross-sectional dependence, which may be due to the presence of common shocks and unobserved components (De Hoyos and Sarafidis, 2006). The outcome of the test for cross-sectional dependence should guide the choice of the appropriate panel unit root test. Thus, in the absence of cross-sectional dependence, first-generation unit root tests have to be performed, otherwise second-generation panel unit root tests should be used. Actually, second-generation panel unit root tests are designed to control for cross-sectional dependency (Gorus and Aslan, 2019; Pesaran, 2007). To detect the cross-section dependency in the series, the Pesaran CD (Pesaran, 2004) test is used.

Next, if all the variables are integrated of order one, cointegration test must be conducted. For the selection of the appropriate panel unit root tests, depending on the presence or not of cross-sectional dependence in the series, the choice of panel cointegration test should be based on cross-dependency test on the disturbances. As a result, if cross-section dependency is detected, a second-generation panel cointegration test should be employed, otherwise a first-generation cointegration test should be performed (Gorus and Aslan, 2019; Westerlund, 2007). This paper makes use of Pesaran's (2004) test of cross-sectional independence, Frees' (1995) test of cross sectional independence and Friedman's (1937) test of cross sectional independence to examine cross-section dependency in the residuals. The cointegration test is to determine whether a long-run equilibrium relationship exists between deforestation, FDI net inflows, economic growth, trade openness and urbanization.

In the case of the rejection of the null hypothesis of no cointegration, slope homogeneity must be tested. Several slope homogeneity tests have been proposed in the literature. The seemingly unrelated regression (SURE) framework of Zellner (1962) can be used for this purpose when the time series dimension is large and the cross section dimension is relatively small (Pesaran and Yamagata, 2008). Although, this approach is particularly attractive, it is not applicable to micro-panels (cross section dimension much larger than time series dimension). Thus, the application of the Hausman (1978) testing approach was proposed by Pesaran *et al.* (1996) where the standard fixed effects estimator is compared to the mean group estimator, but such a testing approach is not applicable to panel data models with strictly exogenous regressors and/or in the case of pure autoregressive models (Pesaran and Yamagata, 2008). Pesaran and Yamagata (2008) have proposed dispersion type tests, which are based on Swamy (1970), and are applicable in the case of panel data models where the cross section dimension could be large relative to the time series dimension.

The long-run equilibrium relationship can be estimated by the fully modified ordinary least squares (FMOLS) technique for heterogeneous cointegrated panel (Neal, 2014; Pedroni, 2001) or by the Kao and Chiang (2001) dynamic ordinary least squares (DOLS) for cointegrated panel data with homogeneous long-run covariance structure across cross-sectional units. It should be noted that FMOLS deals with the issues of endogeneity in the regressors and serial correlation in the error terms leading to consistent parameter estimates in a relatively small sample. As for DOLS method, it eliminates endogeneity, multicollinearity, and serial correlation through including leads and lags of the differenced *I(1)* regressors. This paper resorts to the latter to investigate the long-run relationship between deforestation and the regressors:

$$\begin{aligned} Deforestation_{it} = {} & \alpha_i + \beta_1 FDI_{it} + \beta_2 \ln(GDP_{it}) \\ & + \beta_3 \ln(GDP_{it})^2 + \beta_4 Openness_{it} \\ & + \beta_5 \text{Urbanization}_{it} + \varepsilon_{it} \end{aligned} \qquad (2)$$

where $i = 1, 2, \ldots, N$ for each country in the panel; $t = 1, 2, \ldots, T$ is the time period; α_i are the intercepts, β_j, $j = 1, 2, \ldots, 5$ are the parameters associated with the regressors, ε_{it} captures the residuals, and ln is the natural logarithm.

Panel causality tests are also performed to examine causal relationship between variables. A non-causality test for heterogeneous panel has been introduced by Dumitrescu and Hurlin (2012) which has the advantage to account for two dimensions of heterogeneity such as the heterogeneity of the regression model used to test the Granger causality and the heterogeneity of the causality relationships (Gorus and Alsan, 2019). The null hypothesis in this testing procedure is there is no causal relationship for any of the cross-section units of the panel (Dumitrescu and Hurlin, 2012). Under the alternative hypothesis, there is at least one causality in the cross-section units. In this testing framework, there is no criterion for the selection of the optimal lag length. Consequently, researchers commonly report up to 3 lag lengths or 5 lag lengths in their studies (Gorus and Aslan, 2019). Thus, there is a causal relationship between the series when two out of three or three out of five results suggest the existence of a causal relationship.

3.2. Data and summary statistics

A balanced panel data from 1991 to 2015 obtained from the World Development Indicators (WDI) are used in this study. The Appendix lists the 35 SSA countries included in the paper, so overall there are 875 observations in the panel. All SSA countries are not included in the analyses due to data unavailability on the study period. Table 1 presents the summary statistics on the variables included in the model. The average annual deforestation amounts to 887.385 km^2 over the study period, but with disparities across countries and over years indicated by the minimum of −2,000 km^2 (afforestation) and the maximum of 73,314.1 km^2. Thus, on average, 887.385 km^2 of forest is lost annually in a SSA country. FDI, as a percentage of GDP, amounts on average to 4.049%, with heterogeneities across countries and over time, suggesting that some countries are struggling to attract FDI inflows. These summary statistics depict differences between countries in terms of economic development. Although all SSA countries are classified in the category of developing countries, they do not constitute a homogeneous group. Indeed, the average GDP per capita is US$2,190.738, with the minimum and the maximum being US$161.834 and 20,333.94, respectively. As for trade openness captured by the sum of total exports and imports as a percentage of GDP, its mean value is 73.622%. However, some countries are more open to the rest of the world than others. The size of the urban

Table 1. Summary statistics of the variables

Variables	Obs	Units	Mean	Std. dev.	Min	Max
Deforestation	875	Square km	887.385	2,729.047	−2,000	73,314.1
FDI	875	Percentage of GDP	4.049	9.017	−8.589	161.824
GDP per capita	875	constant 2010 U.S. $	2,190.738	3,199.737	161.834	20333.94
Trade openness	875	Percentage of GDP	73.622	46.697	11.466	531.737
Urban population	875	Number of persons	6,049,692	1.04e + 07	34,731	8.67e + 07

Table 2. Pesaran cross-section dependence test for the series

Variables	CD-test	P-value	Average joint T	Mean ρ	Mean abs (ρ)
Deforestation	7.025***	0.000	25.00	0.06	0.33
FDI	26.826***	0.000	25.00	0.22	0.31
Ln (GDP per capita)	46.715***	0.000	25.00	0.38	0.65
Trade openness	22.705***	0.000	25.00	0.19	0.38
Ln (Urban population)	120.176***	0.000	25.00	0.99	0.99

Note: ***significant at the 1% level of significance.

population also differs across countries, reflecting the heterogeneities in country total population in SSA.

4. Empirical results and discussion

4.1. Empirical results

To avoid estimating spurious regressions, unit-root tests have to be run. The choice of the appropriate panel unit root test is done based on the results of the cross-sectional dependency tests. The results of the cross-section dependency tests are presented in Table 2. These results suggest the presence of cross-section dependency and, therefore, the paper makes use of the second-generation panel unit root tests to examine the order of integration of the series. Therefore, the panel unit root test proposed by Pesaran (2007), which is a simple alternative to panel unit root tests which allow for cross-section dependence, is performed. In this test, the standard augmented Dickey-Fuller (ADF) regressions are augmented with the cross-section averages of lagged levels and first-differences of the individual series. Table 3 presents the Pesaran panel unit root tests. These tests show that the variables are not stationary at level, but they are stationary at the first difference. Indeed, at level, the null hypothesis of a unit root cannot be rejected. So, the variables are integrated of order one.

Table 3. Pesaran panel unit root test results

Variables	Intercept	Intercept and Trend
Deforestation	0.169	−0.377
FDI	−1.736	−1.867
Ln (GDP per capita)	−1.981*	−1.849
Trade openness	−1.567	−2.216
Ln (Urban population)	−1.565	−2.054
ΔDeforestation	−1.995*	−2.268
ΔFDI	−2.074**	−2.047
ΔLn (GDP per capita)	−3.071***	−3.521***
ΔTrade openness	−3.803***	−3.827***
ΔLn (Urban population)	−3.171***	−3.228***

Notes: ***, **, *significant at the 1%, 5%, and 10% level of significance, respectively. Δ is the first difference operator.

As the variables are all integrated of order one, we conduct cointegration tests to investigate the existence of a long-run relationship between deforestation and the explanatory variables. Prior to conducting cointegration tests, cross-sectional dependency tests on the residuals are run in order to select the appropriate testing approach of cointegration. The results of the cross-section dependency tests are presented in Table 4. These results reveal the presence of cross-sectional dependence and favour the use of second-generation panel cointegration test. Moreover, the paper compliments this cointegration test with first-generation cointegration tests. Thus, cointegration is tested through the Westerlund (2007) error-correction-based panel cointegration tests that allow for a large degree of heterogeneity in the long-run cointegration relationship as well as in the short-run dynamics and dependence within as well as across the cross-sectional units. The Pedroni (1999, 2004) heterogeneous panel cointegration test (first generation test) allows for cross-section interdependence with different individual effects. The Westerlund cointegration test results, which is based on four test statistics are reported in Table 5. One of these statistics reject the null hypothesis of no cointegration at 1%. For the Pedroni (1999, 2004) cointegration tests, statistical inference is straightforward as all the tests statistics are distributed $N(0, 1)$. All test statistics, except for group rho-statistic, are significant at least at the 5% level (Table 6). Thus, the Pedroni cointegration tests also indicate that the variables are cointegrated. Hence, there is a cointegration relationship between deforestation, FDI net inflows, GDP per capita and its squared, trade openness and urbanization in SSA over the study period. As a result, the conclusion is that the series tend to move together in the long run.

The long-run equilibrium relationship is estimated by the Kao and Chiang (2001) DOLS.[1] The DOLS results are

[1] Prior to estimating the long-term relationship among the variables, slope homogeneity test must be performed to detect whether to consider country-specific parameters or parameters for the whole panel. Proper slope homogeneity test is not performed. Nevertheless, we test whether the random slope on FDI is statistically significant within a framework of mixed-effects modeling (StataCorp, 2017). The result of this test shows the statistically significance of the random slope on FDI. Therefore, country-specific parameters are considered instead of parameters of the whole SSA.

Table 4. Cross-section dependency on the residuals test results

	With fixed effects estimator		With random effects estimator	
Tests	Statistic	P-value	Statistic	P-value
Pesaran's test of cross sectional independence	3.256***	0.001	64.016***	0.000
Frees' test of cross sectional independence [a]	6.604***	-	23.021***	-
Friedman's test of cross sectional independence	38.204	0.284	517.772***	0.000

Notes: ***significant at the 1% level of significance. [a] For the Frees' test only critical values from Frees' Q distribution are provided.

Table 5. Westerlund cointegration test results

Statistic	Value	Z-value	P-value
Gt	−2.345	−0.852	0.197
Ga	−1.706	7.719	1.000
Pt	−28.349***	−14.089	0.000
Pa	−7.152	0.655	0.744

Note: ***significant at the 1% level of significance.

presented in Table 7. The results for countries such as the Republic of Congo, Ghana, Kenya, Madagascar, Mauritania, Niger and Sierra Leone suggest that FDI net inflows affect positively and significantly the level of deforestation, supporting the pollution haven hypothesis. At the opposite, countries such as Benin, Chad, Gabon, Malawi, Mauritius, Mozambique, Namibia, Rwanda, and Togo support the pollution halo hypothesis. Nevertheless, the remaining countries included in the analyses (Botswana, Burkina Faso, Cape Verde, Cote d'Ivoire, Equatorial Guinea, Guinea Bissau, Nigeria, Senegal, Sudan, Tanzania, Uganda and Zimbabwe) do not support either the pollution haven hypothesis or the pollution halo hypothesis.

The estimation results indicate that only the quadratic term of GDP per capita is statistically significant for Burkina Faso, Equatorial Guinea, Niger and Nigeria. For the other countries, both the linear and the non-linear relationship between deforestation and GDP per capita are not significant. Trade openness appears to be beneficial for forest area in Botswana, Cape Verde, Gabon, Madagascar, Mauritania, Mauritius, Namibia, Niger, Senegal, Sierra Leone and Sudan. However, trade openness is positively and significantly associated with deforestation in Benin, Burkina Faso, Chad, Republic of Congo, Cote d'Ivoire, Equatorial Guinea, Ghana, Malawi, Mozambique, Nigeria, Rwanda, Tanzania, Togo, Uganda and Zimbabwe. Urbanization does not significantly influence deforestation in most of SSA countries. However, urbanization is detrimental to forest area in Mozambique and Tanzania.

Table 6. Pedroni panel cointegration test results for SSA

Panel test statistics		Group mean panel test statistics	
Panel v-statistic	−2.129	-	-
Panel rho-statistic	−2.381	Group rho-statistic	−.355
Panel t-statistic	−16.69	Group t-statistic	−18.85
Panel ADF-statistic	−12.58	Group ADF-statistic	−12.94

Note: All test statistics are distributed $N(0, 1)$, under the null hypothesis of no cointegration and diverge to negative infinity.

Because of the existence of cointegration relationship between the series, the direction of causality between the variables is analyzed by using the Dumitrescu-Hurlin non-causality test. The results show that there is a two-way relationship between FDI and GDP per capita, FDI and trade openness, FDI and FDI and urbanization, GDP per capita and trade openness, GDP per capita and urbanization as well as trade openness and urbanization.[2]

4.2. Discussion

The findings suggest that the Republic of Congo, Ghana, Kenya, Madagascar, Mauritania, Niger, and Sierra Leone support the pollution haven hypothesis, while Benin, Chad, Gabon, Malawi, Mauritius, Mozambique, Namibia, Rwanda and Togo support the pollution halo hypothesis. This implies that a unit increase in FDI net inflows as a percentage of GDP leads to a deforestation ranging from 2.290 km^2 (in Mauritania) to 365.263 km^2 (in Niger) for the former group of countries. For the latter group of countries, a unit increase in FDI net inflows as a percentage of GDP leads to a decrease in deforestation ranging from 2.262 km^2 (in Togo) to 193.951 km^2 (in Benin). These findings may be attributed to various forest-related policies and institutional settings across SSA countries, despite the existence of regional policies. For instance, the forest policy of the Republic of Congo targets the sustainable management of forests and promotes the green economy (République du Congo and FAO, 2014), while this country is still facing challenges in terms of the contribution of the forestry sector to the preservation of the environment.

[2] Details on the non-causality test results are not presented, but are available upon request.

Table 7. DOLS results

Countries	FDI	Ln (GDP per capita)	Ln (GDP per capita) squared	Trade openness	Ln (Urban population)
All countries	68.720***	1581.487	−90.180	−18.193***	451.337
Benin	−193.951***	0	−43.953	46.639***	0
Botswana	−1.807	0	20.689	−3.393***	0
Burkina Faso	0	0	15.077**	1.247***	0
Cape Verde	0	0	3.881	−2.493***	0
Chad	−68.904***	0	−21.021	28.661***	0
Congo, Rep.	5.090***	0	−45.732	21.031***	0
Cote d’Ivoire	0	0	−17.919	10.572***	0
Equatorial Guinea	0	0	1.056***	0.134***	0
Gabon	−148.116***	0	32.928	−27.184**	0
Ghana	8.686***	0	−7.127	0.264***	0
Guinea–Bissau	0	0	2.504	−0.022	0
Kenya	247.328**	0	29.045	−27.495**	0
Madagascar	9.822**	0	48.778	−19.886***	0
Malawi	−21.682***	0	8.000	1.449***	0
Mauritania	2.290***	0	5.258	−2.006***	0
Mauritius	−3.635***	0	0.617	−0.312***	0
Mozambique	−12.574***	0	−25.830	5.676***	172.894***
Namibia	−4.851***	0	14.609	−2.522***	0
Niger	365.263***	–	285.421***	−221.874***	0
Nigeria	0	0	55.564***	18.673***	0
Rwanda	−35.520***	0	−16.920	17.479***	0
Senegal	−1.945	0	34.990	−17.085***	0
Sierra Leone	12.135***	0	13.411	−8.496***	0
Sudan	−255.805	0	1,605.511	−2,616.539***	0
Tanzania	0	0	−183.034	34.972***	611.207***
Togo	−2.262***	0	4.327	0.462***	0
Uganda	0	0	4.689	24.420***	0
Zimbabwe	0	0	39.997	16.708***	0

Notes: ***, **, *significant at the 1%, and 5%, level of significance, respectively. Regressions are not overall significant for countries such as Cameroon, Central African Republic, Congo, Dem. Rep., Guinea, Mali, Seychelles and South Africa.

Note that Kivyiro and Arminen (2014) found that FDI increases carbon dioxide emissions in some African countries, while the opposite effect is observed in others, indicating that the findings of this paper in the forestry sector are in line with those of these authors. In addition, the findings are in some extent in line with Shahbaz *et al*. (2015) that found, in low-income countries, FDI increases carbon dioxide emissions, thus lowering environmental quality. Therefore, industries resulting from FDI in several SSA countries are deforestation-intensive, whereas there is the opposite in other several SSA countries. So, through FDI inflows, the industries are not yet transferring more environmentally friendly technologies from developed or from source countries to a certain number of SSA countries. These findings may be due to the fact that multinationals are depleting forests in several SSA countries.

Statistically significance is found only for the squared of GDP per capita for Burkina Faso, Equatorial Guinea, Niger and Nigeria. Thus, there is no direct link between economic growth and forest cover in most of SSA countries included in this paper during the study period. Therefore, unlike studies that found non-linear relationships between economic growth and pollution, and even for deforestation in of the form of EKC (e.g., Bhattarai and Hammig, 2001), the findings of this paper do not support the existence of EKC. For instance, Copeland and Taylor (2004) stated that the estimation of the EKC is very sensitive to the sample (period, country or group of countries, type of pollutant, etc.).

Trade openness has a negative and significant effect on deforestation in Botswana, Cape Verde, Gabon, Madagascar, Mauritania, Mauritius, Namibia, Niger, Senegal, Sierra Leone and Sudan. However, trade openness is positively and significantly associated to deforestation in Benin, Burkina Faso, Chad, Republic of Congo, Cote d’Ivoire, Equatorial Guinea, Ghana, Malawi, Mozambique, Nigeria, Rwanda, Tanzania, Togo, Uganda and Zimbabwe. In the former category of countries, a unit increase in trade openness (as percentage of GDP) decreases deforestation, ranging from 0.312 km^2 in Mauritius to 2,616.539 km^2 in Sudan. In the latter category of countries, a unit increase in trade openness leads to deforestation from 0.134 km^2 in Equatorial Guinea to 46.639 km^2 in Benin. Hence, international trade is found to improve environmental quality in the first group of SSA countries, while it deteriorates it in the second group. Actually, trade liberalization can lead to the transfer of technologies which are favourable to the environment, in general, especially to forest cover on the one hand. On the other hand, wealthy countries drive deforestation in poorer countries through the importation of forest resources, which leads to deforestation (Busa, 2013). This finding indicates that there is a synergy between trade openness policy, the management of natural resources and the reduction of deforestation in some SSA countries, whereas the opposite exists in the other SSA countries. It is worth noting that Bhattarai and Hammig (2001) found that international trade decreases deforestation in Asia, but not in Africa and in Latin America. Therefore, prudent trade policies foster socially beneficial forest management in some SSA countries. The findings corroborate the fact that the effect of trade openness on deforestation remains controversial.

Urbanization appears to be detrimental to forest area in Mozambique and Tanzania. Thus, a one percent change in urbanization is associated with 1.729 and 6.112 km^2 of forest loss in Mozambique and in Tanzania, respectively. This suggests that the growing trend in urbanization in these two countries is, ceteris paribus, detrimental to forest cover. Accordingly, urbanization does not significantly influence deforestation in most of SSA countries. Indeed, population pressures increase demand for land (houses) and causes deforestation (Culas, 2007). Moreover, as pointed out by several papers (e.g., Behera and Dash, 2017; Bhattarai and Hammig, 2001; Culas, 2007; Solarin *et al*., 2017), urbanization stimulates demand for forest products.

The findings of the causality tests reveal two-way relationship between FDI and GDP per capita, FDI and trade openness, FDI and urbanization, GDP per capita and trade openness, GDP per capita and urbanization and between trade openness and urbanization. These findings confirm the importance of economic growth in attracting FDI and also the beneficial effect of FDI on economic growth in developing countries. In fact, FDI is considered as an engine of economic growth (Kivyiro and Arminen, 2014).

5. Conclusion and policy implications

The aim of this study is to investigate the relationship between FDI inflows, economic growth, trade openness, urbanization and deforestation using the data of 35 SSA countries by applying recent panel data techniques including cross-section dependence tests, panel unit root tests, the Westerlund panel cointegration test, the Kao and Chiang DOLS estimator and the Dumitrescu-Hurlin panel non-causality test for the period 1991–2015. Panel unit root tests reveal that all variables are integrated of order one and panel cointegration tests indicate the existence of a long-run relationship between deforestation, FDI, economic growth, trade openness and urbanization. The DOLS estimation analysis reveals mixed results across SSA countries. The findings show evidence for the validity of the pollution haven hypothesis for the Republic of Congo, Ghana, Kenya, Madagascar, Mauritania, Niger and Sierra Leone, while the pollution halo hypothesis is valid for Benin, Chad, Gabon, Malawi, Mauritius, Mozambique, Namibia, Rwanda and Togo. Trade openness is favourable to forest cover in Botswana, Cape Verde, Gabon, Madagascar, Mauritania, Mauritius, Namibia, Niger, Senegal, Sierra Leone and Sudan, whereas it is associated with deforestation in Benin, Burkina Faso, Chad, Republic of Congo, Cote d'Ivoire, Equatorial Guinea, Ghana, Malawi, Mozambique, Nigeria, Rwanda, Tanzania, Togo, Uganda and Zimbabwe. Thus, trade liberalization does not lead to the transfer of technologies which is favourable to forest cover in all SSA countries. Urbanization is deforestation-intensive only in Mozambique, and Tanzania. So, the expansion of urbanization is at the cost of forest cover in these two countries. Moreover, Dumitrescu-Hurlin panel non-causality test results suggest that the following two-way causal relationships exist in SSA between: FDI and GDP per capita, FDI and trade openness, FDI and urbanization, GDP per capita and trade openness, GDP per capita and urbanization and between trade openness and urbanization.

The results from this study suggest that SSA countries should continue attracting FDI, while a certain number of them should put more emphasis on controlling deforestation associated with FDI inflows to limit GHG concentrations in the atmosphere. Moreover, public policies in Mozambique and Tanzania should target the adoption of a sustainable urbanization plan to counter deforestation. Furthermore, trade policies have to be reinforced in such a way that they will no longer harm forest cover in several SSA countries. It should be noted that a limitation of this research is the fact that it considers aggregate FDI net inflows. Further paths of research could include the analysis of the effects of FDI on deforestation by disaggregating the FDI according to sectors or type of FDI (greenfield/ brownfield, or market-seeking-resource-seeking, strategic FDI).

Acknowledgements

The authors would like to thank the anonymous reviewers and the editor of this journal for providing helpful comments for the substantial improvement of the quality of the paper.

Contributors

Boris Odilon Kounagbè Lokonon has initiated the work. The two co-authors have contributed equally, and approved the final version of the paper.

References

Alix-Garcia, J., 2008. An exploration of the positive effect of inequality on common property forest. *Journal of Development Economics*, 87 (1): 92–105.

Aliyu, M.A., 2005. Foreign direct investment and the environment: Pollution haven hypothesis revisited. Eight Annual Conference on Global Economic Analysis, Lubeck, Germany, 9–11 June 2005.

Allen, J.C., Barnes, D.F., 1985. The causes of deforestation in developing countries. *Annals of the Association of American Geographers*, 75(2): 163–184.

Al-mulali, U., Tang, C.F., 2013. Investigating the validity of pollution haven hypothesis in the gulf cooperation council (GCC) countries. *Energy Policy*, 60(September): 813–819. https://doi.org/10.1016/j.enpol.2013.05.055.

Angelsen, A., Kairnmovitz, D., 1999. Rethinking the causes of deforestation: Lessons from economic models. *World Bank Research Observer*, 14(1): 73–98.

Arcand, J.-L., Guillaumont, P., Jeanneney, S.G., 2008. Deforestation and the real exchange rate. *Journal of Development Economics*, 86(2): 242–262.

Barbier, E.B., 2004. Explaining agricultural land expansion and deforestation in developing countries. *American Journal of Agricultural Economics*, 86(5): 1347–1353.

Behera, S.R., Dash, D.P., 2017. The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. *Renewable and Sustainable Energy Reviews*, 70(April): 96–106. https://doi.org/10.1016/j.rser.2016.11.201.

Bhattarai, M., Hammig, M., 2001. Institutions and the environmental Kuznets curve for deforestation: A crosscountry analysis for Latin America, Africa and Asia. *World Development*, 29(6): 995–1010.

Brazil, 2014. Brazil voluntary national report to eleventh session of United Nations Forum on Forests. Available at nwww.un.org/esa/forests/pdf/national_reports/ unff11/Brazil.pdf (accessed 16 February 2019).

Busa, J.H., 2013. Dynamite in the EKC tunnel? Inconsistencies in resource stock analysis under the environmental Kuznets curve hypothesis. *Ecological Economics*, 94(October): 116–126. https://doi.org/10.1016/j.ecolecon.2013.07.015.

Choumert, J., Motel, P.C., Dakpo, H.K., 2013. Is the environmental Kuznets curve for deforestation a threatened theory: A meta-analysis of the literature. *Ecological Economics*, 90(June): 19–28. https://doi.org/10.1016/j.ecolecon.2013.02.016.

Cole, M.A., 2004. Trade, the pollution haven hypothesis and the environmental Kuznets curve: Examining the linkages. *Ecological Economics*, 48(1): 71–81. https://doi.org/10.1016/j.ecolecon.2003.09.007.

Combes Motel, P., Pirard, R., Combes, J.-L., 2009. A methodology to estimate impacts of domestic policies on deforestation: Compensated Successful Efforts for "avoided deforestation" (REDD). *Ecological Economics*, 68(3): 680–691.

Copeland, B., Taylor, S., 2004. Trade, growth, and the environment. *Journal of Economic Literature*, 42(1): 7–71. https://doi.org/10.1257/002205104773558047.

Cropper, M., Griffiths, C., 1994. The interaction of population growth and environmental quality. *American Economic Review*, 84(2): 250–254.

Culas, R.J., 2007. Deforestation and the environmental Kuznets curve: An institutional perspective. *Ecological Economics*, 61(2–3): 429–437. https://doi.org/10.1016/j.ecolecon.2006.03.014.

De Hoyos, R.E., Sarafidis, V., 2006. Testing for cross-sectional dependence in panel-data models. *The Stata Journal*, 6(4): 482–496.

Deacon, R.T., 1994. Deforestation and the rule of law in a cross-section of countries. *Land Economics*, 70(4): 414–430.

Deacon, R.T., 1999. Deforestation and ownership: Evidence from historical account and contemporary data. *Land Economics*, 75(3): 341–359.

Didia, D.O., 1997. Democracy, political instability, and tropical deforestation. *Global Environmental Change*, 7(1): 63–76.

Dumitrescu, E.-I., Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, 29(4): 1450–1460.

Duveiller, G., Defourny, P., Desclée, B., Mayaux, P., 2008. Deforestation in Central Africa: Estimates at regional, national and landscape levels by advanced processing of systematically-distributed Landsat extracts. *Remote Sensing of Environment*, 112(5): 1969–1981. https://doi.org/10.1016/j.rse.2007.07.026.

Ehrhardt-Martinez, K., 1998. Social determinants of deforestation in developing countries: A cross-national study. *Social Forces*, 77(2): 567–586.

FAO, 2015a. *Vers des Fonds Forestiers Nationaux Efficaces*. FAO, Rome.

FAO, 2015b. *Government Expenditure on Agriculture*. FAO, Rome Available at www.fao.org/economic/ess/esseconomic/expenditure/en (accessed 16 February 2019).

FAO, 2016. *Évaluation des Ressources Forestières Mondiales 2016*. FAO, Rome Available at www.fao.org/forest-resources-assessment/fr (accessed 16 February 2019).

Fowler, M., Abbott, P., Akroyd, S., Channon, J., Dodd, S., 2011. *Forest Sector Public Expenditure Reviews: Review and Guidance Note*. Programeme sur les forêts (PROFOR), Washington, DC.

Frees, E.W., 1995. Assessing cross-sectional correlation in panel data. *Journal of Econometrics*, 69(2): 393–414.

Friedman, M., 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the American Statistical Association*, 32(2): 675–701.

Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving forces of tropical deforestation: Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. *BioScience*, 52(2): 143–150.

German, L., Schoneveld, G., Mwangi, E., 2011. Processes of large-scale land acquisition by investors: Case studies from Sub-Saharan Africa. International Conference on Global Land Grabbing, Sussex, 6-8 April 2011, Land Deals Politics Initiative (LDPI).

Gorus, M.S., Aslan, M., 2019. Impacts of economic indicators on environmental degradation: Evidence from MENA countries. *Renewable and Sustainable Energy Reviews*, 103: 259–268.

Grossman, G.M., Krueger, A.B., 1991. *Environmental Impacts of a North American Free Trade Agreement*. National Bureau of Economic Research, Cambridge, MA.

Grossman, M.G., Krueger, A.B., 1995. Economic growth and the environment. *Quarterly Journal of Economics*, 110(2): 353–377.

Hausman, J.A., 1978. Specification tests in econometrics. *Econometrica*, 46(6): 1251–1271.

He, J., 2006. Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emisssion of sulfur dioxide (SO2) in Chinese provinces. *Ecological Economics*, 60(1): 228–245. https://doi.org/10.1016/j.ecolecon.2005.12.008.

IPCC, 2013. In: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M.M., Allen, S.K., Boschung, J., et al. (Eds.), *Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, MA.

Kao, C., Chiang, M.-H., 2001. On the estimation and inference of a cointegrated regression in panel data. *Advances in Econometrics*, 15: 179–222.

Kearsley, A., Riddel, M., 2010. A further inquiry into the Pollution Haven Hypothesis and the environmental Kuznets curve. *Ecological Economics*, 69(4): 905–919. https://doi.org/10.1016/j.ecolecon.2009.11.014.

Kivyiro, P., Arminen, H., 2014. Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. *Energy*, 74(1): 595–606. https://doi.org/10.1016/j.energy.2014.07.025.

Koop, G., Tole, L., 1999. Is there an environmental Kuznets curve for deforestation? *Journal of Development Economics*, 58(1): 231–244.

Kuznets, S., 1995. Economic Growth and Economic Inequality. *The American Economic Review*, 45(1), 1–28.

McFarland, W., Whitley, S., Kissinger, G., 2015. *Subsidies to Key Commodities Driving Forest Loss: Implications for Private Climate Finance*. Overseas Development Institute, London.

Neal, T., 2014. Panel cointegration analysis with xtpedroni. *The Stata Journal*, 14(3): 684–692.

Neequaye, N.A., Oladi, R., 2015. Environment, growth, and FDI revisited. *International Review of Economics and Finance*, 39(September): 47–56. https://doi.org/10.1016/j.iref.2015.06.002.

Panayotou, T., 1993. *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*. International Labour Organization, Geneva, Switzerland.

Pedroni, P., 1999. Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics*, 61(S1): 653–670.

Pedroni, P., 2001. Fully modified OLS for heterogeneous cointegrated panels. *Advances in Econometrics*, 1: 93–130.

Pedroni, P., 2004. Panel cointegration: asymptotic and finite sample properties of pooled time series tests with application to the PPP hypothesis: New results. *Econometric Theory*, 20(3): 597–627.

Pesaran, H.M., Smith, R., Im, K.S., 1996. Dynamic linear models for heterogenous panels. In: Matyas, L., Sevestre, P. (Eds.), *The Econometrics of Panel Data: A Handbook of the Theory with Applications*, Second Revised edn. Kluwer Academic Publishers, Dordrecht. pp. 145–195.

Pesaran, M.H., 2004. General diagnostic tests for cross section dependence in panels. Cambridge: University of Cambridge, Faculty of Economics, Cambridge Working Papers in Economics No. 0435.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2): 265–312.

Pesaran, M.H., Yamagata, T., 2008. Testing slope homogeneity in large panels. *Journal of Econometrics*, 142(1): 50–93.

République du Congo, FAO, 2014. *La politique forestière de la République du Congo (2014–2025)*. June, Brazzaville, Congo (acessed 27 May 2019).

Rudel, T., Roper, J., 1997. The paths to rain forest destruction: Crossnational patterns of tropical deforestation, 1975–1990. *World Development*, 25(1): 53–65.

Sapkota, P., Bastola, U., 2017. Foreign direct investment, income, and environmental pollution in developing countries: Panel data analysis of Latin America. *Energy Economics*, 64(May): 206–212. https://doi.org/10.1016/j.eneco.2017.04.001.

Selden, T.M., Song, D., 1994. Environmental quality and development: Is there a Kuznets curve for air pollution emissions. *Journal of Environmental Economics and Management*, 27(2): 147–162.

Shahbaz, M., Nasreen, S., Abbas, F., Anis, O., 2015. Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? *Energy Economics*, 51(September): 275–287. https://doi.org/10.1016/j.eneco.2015.06.014.

Solarin, S.A., Al-Mulali, U., Musah, I., Ozturk, I., 2017. Investigating the pollution haven hypothesis in Ghana: An empirical investigation. *Energy*, 124(1): 706–719. https://doi.org/10.1016/j.energy.2017.02.089.

StataCorp, 2017. *Stata: Release 15. Statistical Software*. StataCorp, College Station, TX.

Swamy, P.V., 1970. Efficient inference in a random coefficient regression model. *Econometrica*, 38(2): 311–323.

van Nguyen, P., Azomahou, T.T., 2003. Déforestation, croissance économique et population: Une étude sur données de panel. *Revue Economique*, 54(4): 835–856.

Westerlund, J., 2007. Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, 69(6): 709–748.

World Bank, 2014. *Foreign Direct Investment Flows into Sub-Saharan Africa*. World Bank Group, Washington, DC.

Zellner, A., 1962. An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias. *Journal of the American Statistical Association*, 57(298): 348–368.

Appendix: Countries included in the analyses

Benin	Congo, Democratic Republic	Guinea-Bissau	Namibia	Sierra Leone
Botswana	Congo, Republic	Kenya	Mozambique	South Africa
Burkina Faso	Cote d'Ivoire	Madagascar	Niger	Sudan
Cameroon	Equatorial Guinea	Malawi	Nigeria	Tanzania
Cape Verde	Gabon	Mali	Rwanda	Togo
Central African Republic	Ghana	Mauritania	Senegal	Uganda
Chad	Guinea	Mauritius	Seychelles	Zimbabwe