The Foreign Direct Investment-Environment Nexus: Does Emission Disaggregation Matter?

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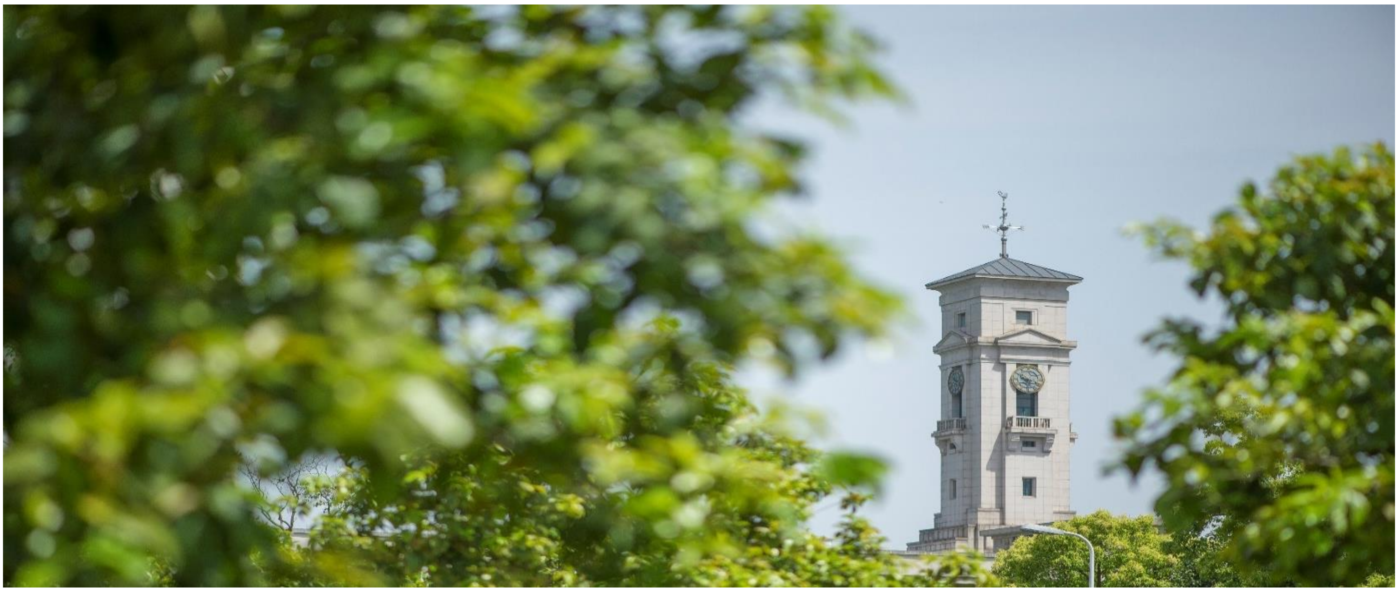

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First published 2021

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Abstract

This paper examines the effect of foreign direct investment (FDI) on CO_2 emissions by using disaggregated emissions data; territorial-based and consumption-based emissions. FDI is measured in three ways; inflow, net inflow, and stock. Employing data over the period 1995-2014 and a number of estimators, the results indicate FDI (whether measured as inflow or net inflow) has negative impact on emissions (irrespective of the measurement). However, the impact is generally found to be greater for the territorial-based emissions. The results of the FDI flow variables largely support the pollution halo hypothesis. Thus, the results are supportive of the robust effect of FDI's positive effect. Regarding the stock measure, the negative effect of FDI is only found for the territorial-based CO_2 emissions. Since the territorial-based emissions capture emissions in the domestic economy only, it is not surprising that the plausible efficiency of FDI stock is found to reduce these emissions rather the consumption-based. FDI stock is now considered part of the local economy. The results of the paper are largely not parallel with previous studies that did not disaggregate CO_2 emissions. This we believe is an indication that the measure of CO_2 matters for the analyses of the FDI-emissions nexus.

Keywords: FDI; environment; consumption-based CO_2 emissions; territorial-based CO_2 emissions; Africa

JEL Classification: F21, F64, N57, N77, Q56

List of Abbreviations

3SLS three stage least squares
AMG augmented mean group
APP Africa Progress Panel
ARDL autoregressive distributed lag
ASEAN Association of Southeast Asian Nations
BRICS Brazil, Russia, India, China and South Africa
CCEMG common correlated effects mean group
CO_2 carbon dioxide
DOLS dynamic ordinary least squares
EKC environmental Kuznets curve
FDI foreign direct investment
FE fixed effects
FMOLS fully modified ordinary least squares
GCC Gulf Cooperation Council
GDP gross domestic product
GHGs greenhouse gases
GMM generalized method of moments
IPCC Intergovernmental Panel on Climate Change
IRENA International Renewable Energy Agency
MENA Middle East and North Africa
NEPAD New Partnership for Africa’s Development
OECD Organisation for Economic Co-operation and Development
OLS ordinary least squares
PMG pooled mean group
POLS pooled ordinary least squares
PVAR panel vector autoregression
RE random effects
SSA sub-Saharan Africa
UNCTADstat United Nations Conference on Trade and Development Statistics

1 Introduction

The last few decades have seen rising economic growth in many sub-Saharan African (SSA) countries, and increasing trade and foreign direct investment (FDI) inflows are important in explaining this growth. In a number of these countries, however, growth has happened at the expense of the environment. This is the case as openness is argued to be associated with greenhouse gases (GHGs) emissions. GHGs released into the environment contribute largely to climate change. It is not surprising therefore that there is intense debate about how to alleviate the harmful consequences of climate change driven mostly by fossil-fuel-based energy (IRENA, 2018: APP, 2017). Many studies do show that climate change and energy consumption are two issues that are critical to the performance of the global economy, particularly in SSA (Sanglimsuwan, 2011; IPCC, 2007; Lau et al., 2014). In the past, environmental pollution from carbon emissions were associated with developed countries but in recent years, focus has been diverted to developing countries because of rapid industrialization and economic growth (Elum & Momodu, 2017).

There has been a growing concern among analysts and policy makers around the world of the threat of increasing carbon dioxide (CO_2) emissions to human life and its very existence. Accordingly, there is pressure by the international community and donors for countries to reduce their CO_2 emissions. Many mitigation strategies have been suggested including improving FDI inflows, education and clean energy sources. This study provides empirical evidence of the role FDI plays in decreasing CO_2 emissions in SSA. The theoretical foundation for the beneficial role of FDI is the assumption that it is instrumental in promoting economic development through the efficiency and augmentation effect (Adams, 2009; Adams et al., 2016). Accordingly, attracting FDI into the region is a key policy agenda of the New Partnership for Africa's Development (NEPAD). Over the last two decades, FDI inflows and foreign aid, forming the main parts of capital inflows into the SSA region have been 3.36 and 3.35 percent of GDP respectively on the average, for the 2000–2017 period. Remittance inflows however was for the same period 2.26 percent of GDP (World Bank, 2018b). For example, FDI inflows into the region rose to US$36 billion in 2006 from US$18 billion in 2004 and attained a peak of US$71 billion in 2014. The past four years, however, show a slight decrease in inflows, US$46 billion, US$ 42 billion, and US$ 46 billion for 2016, 2017 and 2018 respectively and expected to increase to US$52 billion in 2019 (World Investment Report, 2017, 2018, 2019). The reduction in FDI inflows to the region was mainly as a result of fallen oil prices and continuing consequences from the commodity bust, as flows plummeted in economies like the Congo, Mozambique, Nigeria, Egypt and Angola that are mainly commodity exporters (World Bank, 2018). Though the 2018 FDI inflows is below the peak in 2014, however, it represents 3.5 percent of the global inflows, which is higher than the 2 percent for the early 2000s (World Investment Report, 2019). Obviously, it is pertinent to examine how these dramatic inflows impact not only growth but also other important factors like the environment. This issue motivates the study.

In developing countries, multinational firms are arguably more innovative than local firms and later these innovations are spilled over to the domestic economy. Some of these innovations may be environmentally sustainable, as argued by the pollution halo hypothesis (PHH). Churchill et al. (2019) for example have noted that, innovative techniques and processes of firms hurt the environment less, as they result in products that are energy efficient and use less resources in production. As they put it, innovation will certainly benefit the environment or as indicated, innovation has become very important for policy (Pfotenhauer & Jasanoff 2017). Many other studies, including Weina et al. (2016) and Nikzad & Sedigh (2017) suggest that green technology innovations are critical in minimizing global CO_2 emissions. However, Acemoglu et al. (2012) and Jaffe et al. (2002) claim that it cannot be known beforehand the impacts of innovations that are green on the environment (CO_2 emissions) as they could either be positive or negative. These studies suggest that the relationship is an empirical matter. In this study, we contribute to the extant literature by empirically examining the relationship between FDI and environmental degradation.

Unlike previous studies, we split CO_2 emissions into territorial- and consumption-based emissions to examine the differential effect of FDI. Thus, we employ disaggregated CO_2 data for SSA countries. The study accounts for both consumption-based and production-based emissions to avoid or reduce estimation bias. Previous studies have mainly been concentrated on production-based measure (which is also known as the territorial-based measure) CO_2 emissions, which only considers emissions that result from directly burning fossil fuels in the domestic economy. Nevertheless, the consumption-based emissions measure, which accounts for emissions emanating from activities in the domestic economy in addition to emissions from international trade, thus, summing emissions from imports and deducting those in exports is necessary to be accounted for. This is the case as in the global economy activities of production differ from those of consumption (Huang & Jorgenson, 2018). This warrants the importance in considering the differential effect of the two sources. Peters and Hertwich (2008) assert that the consumption-based measure has a number of good sides in addition to considering international trade, such as capturing more of emissions globally. Hasanov, Liddle & Mikayilov (2018) assert that the consumption-based CO_2 emissions are plausibly more important for accounting carbon stock, in addition to their relevance in comprehending the effect of international mitigation endeavors.

Recent studies indicate that about 5Gt of CO_2 is represented in the international trade of services and goods, and most of this CO_2 flows from Annex I countries and economies in transition to Annex II countries (Peters and Hertwich, 2009). A number of current studies have shown the relevance of differentiating between territorial- and consumption-based CO_2 emissions (see Knight & Schor, 2014). Peters and Hertwich (2008) in their study found that about 21.5 percent of CO_2 emissions globally in 2001 were captured in international trade, and as developing countries were usually net importers of CO_2 emissions, developed countries are net exporters. In a number of developing countries, consumption-based emissions exceed the territorial-based emissions. Indeed, Knight and Schor (2014) demonstrate that the association between development and territorial- and consumption-based CO_2 emissions differ depending on the state of development. For example, in their study, they indicate that for a sample of rich countries, the relationship existing between development and the consumption-based CO_2 emissions measure was more robust relative to that between development and territorial-based measures. These studies are supportive of recent studies that show that examination of the two, consumption- and territorial-based CO_2 emissions, are capable of providing constructive comprehension of the possible asymmetry in development-environment (emissions) associations (Huang & Jorgenson, 2018; Lamb et al., 2014; Liddle 2018).

In addition to disaggregating CO_2 emissions, we account for FDI in varied ways; inflows, net inflows and stock, to ascertain whether the measure of FDI matters. Using data from 22 SSA countries over the period 1995-2014, the results generally indicate that FDI (the flow variables) reduces CO_2 emissions irrespective of the measure of emissions. This outcome is largely consistent across a number of estimators; GMM, Hausman-Taylor and Two Stage Least Squares estimators. The implication of the results is that increase in inflows of FDI reduces environmental degradation. This study is among one of the first studies examining the effect of FDI on disaggregated CO_2 emissions, and to the best of our knowledge the first in SSA.

The section that follows provides a brief review of related literature after which the data and estimation model are explained. The results are then presented and discussed, and conclusions drawn.

2 Literature Review

There is a long-standing debate among theorists and empiricists on the direct effect of FDI on economic growth. While this debate is ongoing, the direct effect of FDI on emissions has been thrown into the fray. Presumably, this is because achieving economic growth and lower emissions are mutually exclusive. Anthropogenic emissions are generated from human activities (e.g. farming, construction, transportation and industry etc.) which are essential for the growth process of an economy. The endogenous growth model recognizes the diffusion of technologies as one of the channels through which FDI promotes economic growth in host countries (De Mello, 1997). Thus, the effect of FDI on emissions would depend on the type of technologies FDI transfers into a country, whether dirty or clean. On the one hand, a school of thought argues that growth-induced FDI is associated with higher emissions because FDI increases industrial activities and may introduce dirty technologies into developing countries. On the other hand, another school of thought argues that FDI can promote economic growth without generating more emissions. From this perspective, the inflow of FDI may lead to lower emissions because it may lead to the transfer of clean technologies into developing countries. The direct effect of FDI on emissions is trailed by theoretical and empirical ambiguity. This effect has been explained by two competing hypotheses: pollution haven and pollution halo hypothesis.

2.1 Pollution Haven Hypothesis

The pollution haven hypothesis argues that multinational firms, especially those engaged in ‘dirty’ activities, tend to find countries with lax environmental regulations attractive for their investments. These multinational firms move their production activities into developing countries because they find it cheaper and easier to comply with the weak environmental regulations compared to the stringent environmental regulations guiding production processes in developed countries (Javorcik & Wei, 2004). The developing countries become what Walter & Ugelow (1979) describe as pollution havens. Producers with profit maximization tendencies are likely to locate their production to the least environmentally regulated regions to ensure their sustainability (McGuire, 1982). This is further buttressed by Stavropoulos et al. (2018), who claim that weak environmental regulations in developing countries encourage investment projects that are not allowed in the highly regulated developed countries to be moved there to minimize production cost.

Rezza (2013) finds that stringent environmental regulations in a host country discourages investments from multinational firms with efficiency-seeking motives. A country with a high level of corruption may give room for multinational firms' non-compliance with environmental regulations, thus becomes a pollution haven. Cole et al. (2006) argue that, if host countries' experience high level of corruption, the presence of multinational firms encourages weaker environmental regulations and leads to the creation of a pollution haven. The pollution haven hypothesis is often validated in empirical studies by the existence of an incremental effect of multinationals' investments (FDI) on the emissions level. Zugravu-Soilita (2017) argues that FDI increases emissions in countries that possess average capital endowments and weak environmental regulations. There has also been a number of empirical studies that give support to this hypothesis (see, for instance, Blanco et al., 2013; Cole, 2004; He, 2006; Solarin et al., 2017; Wagner & Timmins, 2009). However, Zheng and Shi (2017) argue that the validity of the pollution haven hypothesis is contingent on the nature of environmental policy and industrial characteristics.

2.2 Pollution Halo Hypothesis

The pollution halo hypothesis contends that the entry of multinational firms introduces superior and efficient (clean) technologies into a host country, which are of benefit to the environment. Multinational firms use low-polluting technologies compared to domestic firms in developing countries (Eskeland & Harrison, 2003; Kim & Adilov, 2012). The presence of multinationals engaging in FDI tends to encourage host countries to adopt stringent environmental regulations (Gallagher and Zarsky, 2007; Zarsky, 1999; Zugravu-Soilita, 2017). However, Dong et al. (2012) argue that technology gap and market size of trading countries would determine whether FDI would make environmental regulations stringent or not.

In sharp contrast to the pollution haven hypothesis, the pollution halo hypothesis argues that FDI brought into developing countries by multinational firms reduces pollution. The influx of FDI to developing countries helps in the transfer of technology and management practices that cause lower carbon emissions leading to what Zarsky (1999) describes as "pollution halos". Similarly, Stavropoulos et al. (2018) argue that FDI flows into developing countries could help to promote industry competitiveness and environmental performance. Adams (2008) attributes the positive view of FDI's impact on the environment to its two main effects; efficiency and augmentation of domestic investment, which result in increase in the total investment necessary for economic growth. At the same time, the productive efficiency associated with its efficiency effect (transfer of marketing, managerial, and technological) could help in reducing CO_2 emissions (Adams, 2008). Lee (2013) explains that the externalities associated with productivity gains promote the use of more efficient energy sources and the subsequent improvement in environmental quality. The pollution halo hypothesis has been validated in a number of studies by the negative effect of FDI on emissions (see, for instance, Bao et al., 2011; Kim & Adilov, 2012; Solarin & Al-mulali, 2018; Zugravu-Soilita, 2017). Demena and Afesorgbor (2020) recently find support for the pollution halo hypothesis through a meta-analysis which considered 65 empirical studies.

Table 1 summarizes selected empirical studies on the nexus between FDI and emissions (pollution), which validate either the pollution haven or pollution halo hypothesis. Indeed, it is evident that the empirical ambiguity in this nexus is far from being settled. This is also the case for Africa, although there is a limited number of studies. This present study is sequel to Adams & Opoku (2020), who primarily examine the impact of trade performance (imports, exports and total trade) on pollution in Africa. We take a cue from this study by using disaggregated CO_2 emissions– territorial- and consumption-based CO_2 emissions. We extend the study by accounting for FDI via its stock and flow measurements. Thus, this study simultaneously considers different measurements for CO_2 emissions and FDI. By and large, this study ascertains whether the nature of FDI and CO_2 emissions measurement matter for the FDI-emissions nexus.

Table 1: Summary of selected empirical studies on FDI-emissions (pollution) nexus

Study	Sample	Sample period	Estimation technique(s)	Supporting hypothesis
Adams & Opoku (2020)	22 SSA countries	1995-2014	System GMM	Pollution halo
Bakhsh et al. (2017)	Pakistan	1980-2014	3SLS	Pollution halo
Bao et al. (2011)	29 Chinese provinces	1992-2004	3SLS	Pollution halo
De Pascale et al. (2020)	36 OECD countries	2000-2017	POLS, FE, RE, DOLS	Pollution haven
Gorus & Aslan (2019)	9 MENA countries	1980-2013	DOLS	Pollution haven
Huang et al. (2019)	30 Chinese provinces	1997-2014	Panel quantile regression	Pollution halo
Jiang (2015)	28 Chinese provinces	1997-2012	FE	Pollution haven
Jiang et al. (2018)	150 Chinese cities	2014	Spatial econometric regression	Pollution halo
Jebli et al. (2019)	22 Central and South American countries	1995-2010	DOLS, FMOLS	Pollution halo
Kahia et al. (2019)	12 MENA countries	1980-2012	PVAR	Pollution halo
Kim & Adilov (2012)	164 countries	1961-2004	OLS	Pollution halo
Liu et al. (2017)	112 Chinese cities	2002-2015	Difference and System GMM	Pollution halo
Liu et al. (2018)	285 Chinese cities	2003-2014	Spatial panel regression	Pollution halo
Mahmood et al. (2019)	Egypt	1990-2014	ARDL	Pollution halo
Nasir et al. (2019)	5 ASEAN countries	1982-2014	DOLS, FMOLS	Pollution haven
Opoku & Boachie (2020)	36 African countries	1980-2014	PMG	Pollution haven
Rafindadi et al. (2018)	6 resource-based GCC countries	1990-2014	PMG	Pollution halo
Rafique et al. (2020)	BRICS countries	1990-2017	AMG	Pollution halo
Salahuddin et al. (2018)	Kuwait	1980-2013	ARDL	Pollution haven
Sapkota & Bastola (2017)	14 Latin American countries	1980-2010	FE, RE	Pollution haven
Sarkodie & Strezov (2019)	China, India, Iran, Indonesia and South Africa	1982-2016	Panel data regression with Driscoll-Kraay standard errors, U test, panel quantile regression	Pollution haven
Seker et al. (2015)	Turkey	1974-2010	ARDL	Pollution haven
Shahbaz et al. (2018)	France	1955-2016	Bootstrapping ARDL	Pollution haven
Shahbaz et al. (2019)	United States	1965-2016	ARDL	Pollution haven
Solarin & Al-mulali (2018)	20 developed and developing countries	1982-2013	AMG, CCEMG	Pollution halo
Zakaria & Bibi (2019)	5 South Asian countries	1985-2015	FE	Pollution halo
Zang et al. (2019)	30 Chinese provinces	2004-2016	FE	Pollution halo
Zhang & Zhang (2018)	China	1982-2016	ARDL	Pollution haven
Zhu et al. (2016)	ASEAN-5 countries	1981-2011	Panel quantile regression	Pollution halo

3 Methodology

In this section, we describe the methodology used in the paper. Specifically, it contains the following subsections; empirical model and data, and estimation method.

3.1 Empirical model and data

Generally, we follow the empirical studies reviewed and estimate the effect of FDI on CO_2 emissions based on the model below;

$$CO_{2_{it}} = \alpha + \beta_1 FDI_{it} + \beta_2 Trade_{it} + \beta_3 Y_{it} + \beta_4 Y_{it}^2 + \beta_5 Pop_{it} + \varepsilon_{it} \quad (1)$$

where i and t represent country (22 countries) and time (1995-2014) respectively. CO_2 is the dependent variable and it denotes environmental degradation, and in this case CO_2 emissions. CO_2 is captured mainly in two ways, and as a result can alternatively take consumption-based CO_2 emissions per capita ($COcons$) or territorial-based CO_2 emissions per capita ($COterr$). $COcons$ is computed based on the use of fossil fuels domestically in addition to the emissions from imports less exports (Peters et al., 2011). In essence, it captures emissions resulting from domestic activities (excluding exports) plus emissions embodied in imports. It is computed in million tons of carbon per year. $COterr$, also computed in million tons of carbon per year, represents CO_2 emissions from only domestic activities (Boden et al., 2013; Lamb et al., 2014). This measure captures exports and exclude imports of goods and services.

FDI represents foreign direct investment, and we capture it in three ways; i) inward FDI as a percentage of GDP, ii) net inflows of FDI as a percentage of GDP, and iii) FDI stock as a percentage of GDP. We seek to explore how different measures (flow and stock) of FDI affect our dependent variable(s). The flow measures show changes in FDI over a period of time while the stock measures indicate the amount of FDI accumulated in a certain period. As the flow measures are based on current account inflows, the stock measure estimates the total cumulative value of foreign owned investment or capital in a nation (Iamsiraroj, 2016). Stock due to the accumulation of flows may more capture long-run effects effectively (Herzer, 2010; Tsai, 1995). Baltabaev (2014) also justified his use of stock with the argument that the stock of FDI captures the already established multinationals and may have more impact on the local economy, and hence the environment.

$Trade$ represents trade openness, that is total trade (summation of total exports and imports) of goods and services as a percentage of GDP. Y proxy for economic growth, and it measured as the log of per capita GDP. To account for the environmental Kuznets curve (EKC) hypothesis in the model, we included the squared of economic growth as Y^2 (Grossman & Krueger, 1991; Saboori, Sulaiman & Mohd, 2012). The inclusion of the Y^2 implicitly captures the curvature of the EKC (Wang, 2012). Pop represents population, and it measured as the log of total population. Dietz and

Rosa (1994) and Ehrlich and Holdren (1971) argue that changes in population affect the environment. CO_2 emissions are higher in countries with larger population (Aluko & Obalade, 2020; Martínez-Zarzoso et al., 2007). β_1- β_5 are parameters to be estimated, and ε_{it} is the error term.

We employ data from 22 SSA countries (Benin, Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Guinea, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Nigeria, Rwanda, Senegal, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe). We obtained $COcons$ and $COterr$ from Peters et al. (2011) and Boden et al. (2015), inward FDI and FDI stock from the United Nations Conference on Trade and Development Statistics (UNCTADStat online). All other remaining variables are sourced from the online database of the (World Development Indicators). The data for the study spans from 1995-2014. Note that sample size of the study is selected based on data availability.

Table 2 displays a summary of the variables and the descriptive statistics, and Table 3 the correlation matrix of the variables. In total we have 440 country-year observations, giving us an indication of a balanced panel. On the average, the emissions of the territorial based CO_2 emissions is greater than that of the consumption based (Table 2). On the average net inflows of FDI as a percentage of GDP (2.982) does not vary much from inward FDI as a percentage of GDP (2.840). This we believe is due to the fact that outward FDI in Africa is very minimal, hence netting it from inward FDI does not generate much difference from the inward FDI. Expectedly, the stock FDI, measuring FDI at a particular point in time, is on the average substantially greater (20.706) than the FDI flow variables (Table 2). The correlation matrix results (Table 3) show negative association between the FDI flow variables (inflow and net flow) and the CO_2 measures. However, for the stock variable, there is an indication of a positive association. Obviously, we cannot be conclusive based on these outcomes as the analyses do not cater for other important variables, and the method is not robust. We subject these results to a more rigorous analysis in the subsequent sections to ascertain whether it holds with the inclusion of other variables and across varied estimation methods. For the variables on the right-hand side of Equation 1, with the exception of GDP and GDP squared that show to be highly correlated (0.997), the correlation between the other variables do not indicate a problem of multicollinearity. Despite the high correlation, neither GDP nor its squared will be dropped as they are theoretically important variables to include on the right hand-side of the equation (Wang, 2012).

3.2 Estimation Strategy

The main estimation method we employ to explain the relationship between our explanatory and the dependent variables is the system generalized method of moments (GMM). The use of the GMM is motivated by the fact that it enables us to skip the tedious task of finding and theoretically justifying external instruments for identification. Bazzi & Clemens (2013) argue that many of the instrumental variables employed in empirical studies may be either weak, invalid or both. With this the instrumental variables may just explain a little variation of the endogenous variable and this could lead to severe biases in the regression estimates (Bound, Jaeger & Baker, 1995). To circumvent this, we employ the GMM which is able to control for unobserved heterogeneity and endogeneity by allowing the inclusion of lagged dependent and independent variables as

Table 2: Descriptive Statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
COcons	Consumption-based carbon dioxide emissions	440	21.813	60.846	0.462	360.709
COterr	Territorial-based carbon dioxide emissions	440	26.559	89.293	0.461	501.377
Trade	Total trade as a percentage of GDP	440	65.803	23.690	23.981	132.199
FDI_WB	FDI net inflows as a percentage of GDP (World Bank)	440	2.982	3.995	-0.900	41.810
FDI_UNCTAD	Inward FDI as a percentage of GDP (UNCTAD)	440	2.840	3.883	-0.532	38.549
FDI Stock	FDI Stock as a percentage of GDP (UNCTAD)	440	20.706	19.464	0.526	146.915
Income	Log of GDP per capita	440	6.689	0.994	4.956	9.226
Incomesq	Log of GDP per capita squared	440	45.727	14.112	24.557	85.112
Population	Log of total population	440	16.364	1.084	13.931	18.988

Table 3: Correlation Matrix

	1	2	3	4	5	6	7	8	9
1. COcons	1.000								
2. COterr	0.994	1.000							
3. Trade	-0.118	-0.122	1.000						
4. FDI_WB	-0.071	-0.084	0.288	1.000					
5. FDI_UNCTAD	-0.065	-0.079	0.263	0.950	1.000				
6. FDI_Stock	0.157	0.139	0.275	0.558	0.563	1.000			
7. Income	0.428	0.414	0.503	0.057	0.061	0.061	1.000		
8. Incomesq	0.438	0.424	0.510	0.050	0.052	0.052	0.997	1.000	
9. Population	0.386	0.358	-0.620	0.011	0.014	0.014	-0.312	-0.333	1.000

internal instruments (Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998; Holtz-Eakin, Newey, & Rosen 1988). The estimator also enables us to overcome other estimation challenges, such as the combination of a short panel, a dynamic dependent variable, and fixed effects (Roodman, 2009).

The estimation of the GMM follows two main procedures; the first procedure first differences [1] to eliminate any possible bias that may come from time invariant unobserved heterogeneity. Regarding the second procedure, the model is estimated by using the lagged values of the explanatory variables as internal instruments for the current explanatory variables. These instruments are collected from the set of lagged dependent or independent variables. Level variables may be weak instruments for the first differenced equations, and also first differencing may also intensify the effect of measurement errors on the regressand (Arellano & Bover, 1995). This is overcome by adding the equations in levels in the estimation procedure (Arellano & Bover, 1995; Blundell & Bond, 1998). The first differenced variables can then be used as instruments for the equations in levels in a system of equations including both equations in levels and first differences. This leads us to the system GMM. We test the validity of our estimator in two ways; first is the test for second second-order serial correlation which enables us to determine whether or not we have added enough number of lags to accommodate for the dynamic aspect of the model. The second test is the Hansen J test of over-identification, which enables us to assess the validity of the instruments. We use one lag of all explanatory variables as instruments in the estimation.

4. Results and Discussion

The results and discussion of the study are presented in this section. The main results of the study estimated by the system GMM are presented in Tables 4-5, and in each Table, we present 6 models differentiated by the measure of FDI used. The dependent variables in Table 4-5 are respectively the territorial- and consumption-based CO_2 emissions.

From the results in Table 4 where the dependent variable is territorial-based CO_2 emissions, we can infer that irrespective of the estimated model, the coefficients of FDI (whether measured as inflows, net flow or stock) are consistently negative and statistically significant at the 1 percent level of significance. In Table 5, where the dependent variable is consumption-based

CO_2 emissions, we find that with the exception of models (3 and 6) using FDI stock as the main explanatory variable, the coefficients of FDI (measured as inflow and net inflow) are negative and significant (statistically) in the other estimations. This buttresses the results in Table 4.

Table 4: Effect of FDI on Territorial-based CO_2 Emissions (System-GMM Estimation)

	(1)	(2)	(3)	(4)	(5)	(6)
	FDI_WB	FDI_UNCTAD	FDI_Stock	FDI_WB	FDI_UNCTAD	FDI_Stock
L.COterr	0.999***	0.999***	1.004***	0.994***	0.993***	0.996***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0617***	0.061***	0.066***	0.0517***	0.0514	0.0519***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.418***	-0.484***	-0.165***	-0.393***	-0.459***	-0.164***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Income	1.720***	1.760***	2.384***	-10.61***	-8.355***	-12.664***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Incomesq				0.891***	0.745***	1.095***
				(0.000)	(0.000)	(0.000)
Population	4.593***	4.605***	5.017***	5.128***	5.148***	5.824***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-88.75***	-89.086***	-98.462***	-55.00***	-63.675***	-60.063
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR(2)	-1.036	-1.040	-1.035	-1.037	-1.0414	-1.037
Sargan Test	19.924	19.077	19.084	19.985	19.081	18.582
Instruments	41	41	41	42	42	42
Observations	418	418	418	418	418	418
No. of countries	22	22	22	22	22	22

Standard errors are in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Dependent variable: Territorial-based CO_2 emissions.

The results consistently indicate a statistically significant negative relationship between the flow measures of FDI and CO_2 emissions, indicating that irrespective of the measure of CO_2 emission, an increase in FDI flow could potentially improve environmental deterioration, in a way of reduction in carbon emissions. Considering the magnitude of the coefficients, the results indicate that the fall in the territorial-based CO_2 emissions is greater than the consumption-based emissions. The implication is that with increase in FDI inflows, the reduction in territorial-based CO_2 emissions is more significant than the consumption-based CO_2 emissions. Thinking along the lines of trade, the inflows of FDI can be likened more to inflows of imports. Since consumption-based CO_2 emissions includes emissions embodied in imports, we believe that the countries contained in our sample attract more CO_2 emissions from imports, and though

FDI reduces the emissions, the reduction is lesser relative to the territorial-based emissions. The emissions emanating from imports (which may be as a result of FDI inflows) increase the territorial-based emissions already contained domestically. As a result, the reduction in emissions following efficiency of FDI is greater for the territorial-based emissions than the consumption-based. Regarding the results for the FDI stock measure, the negative relationship is only found for the models using territorial-based CO_2 emissions as the dependent variable. The stock measure of FDI in a way captures the domestication of FDI in the local economy. It captures the accumulative effect of FDI at a particular point in time. FDI stock represents accumulated FDI which is now considered part of the local economy. The efficient effect of FDI is more likely to be felt in the stock variable as it measures the accumulative effect of the FDI. Territorial-based measure of CO_2 emissions contains only domestic emissions, as a result the efficient impact of FDI stock is more likely to have a negative effect. It is therefore not surprising that the plausible efficiency of FDI is found to reduce territorial emissions. The results however, indicate a positive relationship between the stock measure of FDI and the consumption-based CO_2 measure. This implies that increase in FDI stock is likely to be associated with increase in consumption-based CO_2 emissions. This result may be explained by the fact that the consumption-based measure excludes emissions from exports and adds that from imports. Since the stock measure effectively captures the long-run effects of FDI (Herzer, 2010; Tsai, 1995), the results can also be explained to indicate that the long-run effect of FDI on consumption-based CO_2 emissions is positive.

Table 5: Effect of FDI on Consumption-based CO_2 Emissions (System-GMM Estimation)

Variables	(1) FDI_WB	(2) FDI_UNCTAD	(3) FDI_Stock	(4) FDI_WB	(5) FDI_UNCTAD	(6) FDI_Stock
L.COcons	0.983***	0.985***	0.987***	0.980***	0.983***	0.979***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Trade	0.0258***	.0272***	-0.010***	0.0244***	0.026***	-0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI	-0.320***	-0.375***	0.047***	-0.300***	-0.357***	0.0504***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Income	4.653***	4.573***	3.884***	-1.884	0.804	-8.527***
	(0.000)	(0.000)	(0.000)	(0.158)	(0.527)	(0.000)
Incomesq				0.447***	0.264***	0.867***
				(0.000)	(0.001)	(0.001)
Population	-1.635***	-1.384***	-1.785***	-1.051***	-1.093***	-1.998***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-3.668	-7.358	3.938**	10.220*	0.947	51.245
	(0.419)	(0.152)	(0.048)	(0.074)	(0.859)	(0.000)
AR(2)	1.242	1.227	1.233	1.244	1.228	1.239
Sargan test	16.651	19.402	18.238	17.052	19.873	16.703
Instruments	41	41	41	42	42	42
Observations	418	418	418	418	418	418
No of countries	22	22	22	22	22	22

Standard errors are in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Dependent variable: Consumption-based CO_2 emissions.

The results of the FDI flows, though generally support the pollution halo hypothesis (Kahia et al., 2019; Huang et al., 2019; Jebli et al., 2019), it is not in tandem with some empirical studies (see for example, Gorus & Aslan, 2019; Opoku & Boachie, 2020; Salahuddin et al., 2018). We believe that a potential reason for the difference in results is the measure of the CO_2 emissions. Prior studies did not split CO_2 emissions as in this study. In essence, the impact of FDI on CO_2 emissions hinges on the measure of emissions. Besides, the sample sizes employed also differ remarkably. The present study employs a more recent data. The results generally tell us that potentially the recent influx of multinationals in the region come with superior technologies that do not hurt the environment but rather improves it (Doytch and Uctum, 2016; Wang, 2017). Temurshoev (2006) argues that environmental regulations in developing countries may not be too strict to curb environmental deterioration because these countries are poor. It must however be emphasized that a number of these countries have improved economically since the 2000s and have perhaps started taking issues of the environment seriously.

The results indicate that irrespective of the FDI measure (whether inflows or net flows), the effect of FDI on CO_2 emissions is statistically negative, also buttressing the pollution halo hypothesis. We undertake further robustness checks by estimating the results in Tables 4-5 using the two stage least squares[1] and Hausman-Taylor[2] estimations (Tables 6-7). Generally, we find that irrespective of the measure of CO_2 emissions, the coefficients of FDI (measured as inflow or net inflow) are negative buttressing the previous results. Howbeit, the stock measure of FDI generally shows positive connection between FDI and emissions. For the case where the stock measure turns positive coefficient, we believe that it is as a result of the accumulation and long-run effect as explained afore.

[1] Using the first lags of FDI and trade openness as instruments. The Cragg-Donald test of a valid instrument shows that the instruments are valid as they all pass the Cragg-Donald minimum requirement of an F-statistic value of 10 or greater.
[2] Choosing FDI and trade as the endogenous variables.

Table 6: Effect of FDI on CO_2 Emissions (2SLS Estimation)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Territorial-based CO_2 Emissions						**Consumption-based CO_2 Emissions**					
Trade	0.296**	0.293**	0.147	0.260**	0.251**	0.135	0.323***	0.317***	0.169	0.284**	0.271**	0.156
	(0.013)	(0.013)	(0.163)	(0.022)	(0.026)	(0.176)	(0.007)	(0.008)	(0.110)	(0.012)	(0.016)	(0.115)
FDI_WB	-0.807**			-0.645**			-0.713**			-0.535*		
	(0.012)			(0.038)			(0.029)			(0.085)		
FDI_UNCTAD		-0.813**			-0.590*			-0.686**			-0.440	
		(0.011)			(0.05)			(0.035)			(0.159)	
FDI_Stock			0.126**			0.114**			0.166***			0.153***
			(0.026)			(0.032)			(0.004)			(0.004)
Income	16.478***	16.416***	15.812***	-58.487***	-58.437***	-64.536***	16.234***	16.125***	15.992***	-65.995***	-66.514***	-70.727***
	(0.000)	(0.000)	(0.000)	(0.00)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Incomesq				5.249***	5.234***	5.642***				5.757***	5.779***	6.090***
				(0.00)	(0.000)	(0.000)				(0.000)	(0.000)	(0.000)
Population	-24.921**	-24.931**	-29.969***	-10.612	-10.718	-14.007	-18.929*	-18.969*	-25.229**	-3.233	-3.278	-8.001
	(0.013)	(0.013)	(0.003)	(0.285)	(0.281)	(0.157)	(0.061)	(0.061)	(0.013)	(0.745)	(0.742)	(0.416)
Cragg-Donald F-statistic	70.495	73.037	101.134	69.007	70.833	100.893	70.495	73.037	101.134	69.007	70.833	134.799
Observations	418	418	418	418	418	418	418	418	418	418	418	418
No. of countries	22	22	22	22	22	22	22	22	22	22	22	22

Standard errors are in parentheses. * p<0.05, ** p<0.01, *** p<0.001. Dependent variables: Territorial- and consumption-based CO_2 emissions respectively.

Table 7: Effect of FDI on CO_2 Emissions (Hausman-Taylor Estimation)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
	Territorial-based CO_2 Emissions						**Consumption-based CO_2 Emissions**					
Trade	0.159***	0.156***	0.092	0.109*	0.105*	0.059	0.153**	0.149**	0.084	0.106*	0.100*	0.052
	(0.009)	(0.010)	(0.117)	(0.060)	(0.069)	(0.286)	(0.011)	(0.012)	(0.148)	(0.059)	(0.073)	(0.331)
FDI_WB	-0.453**			-0.272			-0.384**			-0.187		
	(0.015)			(0.130)			(0.041)			(0.297)		
FDI_UNCTAD		-0.471**			-0.257			-0.382**			-0.147	
		(0.015)			(0.168)			(0.050)			(0.428)	
FDI_Stock			0.063			0.072			0.105**			0.117***
			(0.194)			(0.113)			(0.030)			(0.009)
Income	13.045***	13.001***	12.680***	-66.463***	-66.418***	-69.347***	11.862***	11.803***	11.852***	-75.197***	-75.483***	-77.428***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Incomesq				5.618***	5.611***	5.821***				6.189***	6.203***	6.363***
				(0.000)	(0.000)	(0.000)				(0.000)	(0.000)	(0.000)
Population	-11.479	-11.290	-14.669**	1.947	1.983	-0.688	-1.848	-1.741	-6.428	11.207*	11.191*	7.552
	(0.101)	(0.107)	(0.043)	(0.775)	(0.771)	(0.922)	(0.771)	(0.784)	(0.330)	(0.057)	(0.058)	(6.079)
Constant	74.366	71.893	130.825	138.932	138.690	193.194	-64.317	-65.350	11.812	30.382	32.214	97.786
	(0.487)	(0.501)	(0.237)	(0.167)	(0.168)	(0.061)	(0.492)	(0.485)	(0.904)	(0.721)	(0.705)	(0.265)
Observations	440	440	440	440	440	440	440	440	440	440	440	440
No. of countries	22	22	22	22	22	22	22	22	22	22	22	22

Standard errors are in parentheses. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Dependent variables: Territorial- and consumption-based CO_2 emissions respectively.

Regarding the other control variables, trade openness is found to largely have positive coefficients (except in few instances that it turns negative) irrespective of the measure of CO_2 emissions (Tables 4-5), indicating that increase in trade openness generally harm the environment. These results support the pollution haven hypothesis, which essentially asserts that opening up for trade by developing countries will eventually make their countries polluted (Jebli et al., 2019; Zeng et al., 2019). The coefficients of economic growth are found to be consistently positive initially (see Models 1-3 of Tables 3-4 and Models 1-3 and 7-9 of Tables 6-7). This indicates that increasing economic growth is potentially associated with rising deterioration of the environment in the form of emissions of CO_2. This holds irrespective of the measure of emissions. Nevertheless, when we augment the models with the squared of economic growth to test the thesis that when economies attain higher economic growth, environmental quality sets in, our results indicate otherwise (see Models 4-6 of Tables 4-5). With the addition of the squared of economic growth, the results indicate that at the early stages of growth, the effect of growth could rather be not harmful to the environment, howbeit becomes harmful at higher levels of growth. This defies the EKC hypothesis (Omri et al., 2019; Zeng et al., 2019). Similar results are found when we use other estimation methods (see Tables 6-7). The effect of population is mixed, and it depends on the measure of CO_2 emissions. Generally, population growth is found to potentially increase emissions of the production-based (territorial-based) CO_2 emissions, and reduce that of the consumption-based measure.

5 Conclusions

This study examined the effect of FDI on CO_2 emissions by employing disaggregated emissions data; territorial-based and consumption-based emissions for the sample period 1995-2014. The study also measured FDI in three ways; net inflows of FDI, inward FDI and FDI stock. The results largely indicate that the FDI flow variables (whether measured as net inflow or inward) have negative impact on emissions (irrespective of the measurement). This implies that, with the increase in FDI flows, environmental degradation is reduced. The effect of the reduction is found to be greater for territorial-based CO_2 emissions. The results support the pollution halo hypothesis which argues that FDI does not increase emissions (hence does not harm the environment) as multinational firms possess superior technologies that protect the environment. Also, considering the sample size, the results more or less implies that FDI flows into the SSA region in recent years may be relatively environmentally friendly. The results of the paper are largely not parallel with previous papers that did not disaggregate CO_2 emissions. This is an indication that the measure of CO_2 may matter for the analyses of the FDI-emissions nexus. In other estimations, the stock of FDI which captures the overall cumulative impact of long-run FDI was found to have positive effect on CO_2 emissions.

Considering the results of the study, we suggest that the government and other policymakers enact more attractive packages to attract FDI and multinational firms with green technologies to protect the environment. The economies of SSA need FDI for their development. However, this development should not come at the expense of the environment as the eventual environmental consequences may exceed the economic gains. As a result, right from the onset, the government should work to attract FDI that will improve environmental quality. For multinational or FDI-based firms already existing in the SSA economies, the government can tighten environmental regulations to ensure that these firms adopt environmentally friendly strategies.

In this study, we do consider potential determinants of our main variable of interest, that is FDI. Factors such as governance/corruption and conflict can affect FDI inflows. However, since we more interested in the effect of FDI on the environment, we did not consider its determinants. This may be a potential limitation of our study.

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