Globalization and Environmental Pollution in Sub-Saharan Africa

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Abstract
Using data from 38 Sub-Saharan African countries for the period from 1980 to 2017, this paper investigates the effects of globalization on environmental pollution by making distinction between the *de jure* and *de facto* aspects. The *de facto* globalization measures include variables that represent flows and activities whereas the *de jure* measures include variables that represent economic policies that, in principle, orient flows and activities. The second generation panel data tests by Pesaran enables to check the cross-sectional dependence and unit root of the variables. The panel specification with the estimation approach by Hoechle is used to account for spatial dependence, heteroscedasticity and errors autocorrelation. We find that globalization and its *de jure* and *de facto* aspects contribute positively to environmental pollution in SSA by increasing the carbon dioxide (CO2) emission. Policymakers must take action to control long-run CO2 emission for sustainable development.

Keywords: Environmental pollution; Globalization; Cross-sectional dependence; Panel; Sub-Saharan Africa.
JEL Classification Codes : C23, F64, O55

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1. Introduction

Globalization has experienced a spectacular growth in the recent decades in both developed and developing countries (Gygli et al., 2019; BATAKA, 2020). Several reasons are attributable to the increased magnitude of globalization over the last decades. The first reason is attributed to is the economic liberalization through dismantling of the constraints on trade flows, foreign direct investment (FDI) and capital movement. The second reason emanates from the proliferation of modern tools of information sharing, particularly the amplified use of the New Information and Communication Technologies (NICTs) (Internet, Mobile Phone, WhatsApp, Facebook, Twitter). The increased migratory and tourist flows, and the participation of countries in international missions have also fueled this globalization process. The globalization challenges, according to winners and losers and its effects on macroeconomic variables (economic growth, inequalities, tax revenues) have worried scholars for several years (Baliamoune-Lutz, 2006; Egbetunde and Akinlo, 2015; Majidi, 2017; Zahonogo, 2018; BATAKA, 2019). However, the upsurge of the phenomenon over the past two decades seems to shift the debate to the effects of globalization on the environmental pollution.

Indeed, the harmful consequences of environmental pollution on human health, biodiversity and economic development (Kampa and Castanas, 2008; Nowak *et al*., 2014; Jin *et al*., 2017) have led to the recrudescence of studies looking the factors that stimulate the environmental pollution. The environmental pollution can originate from the emission of some toxic wastes and gases, but the carbon dioxide (CO2) is the most commonly recognized pollutant. Regarding the determinants of environmental pollution, theoretical and empirical studies show that globalization through its different dimensions can contribute to CO2 emission. The economic dimension of globalization foresees the removal of obstacles to free trade, capital movement, foreign direct investment (FDI),portfolio investment movement and the information relating to these phenomena. According to this conception, economic globalization can lead to polluting multinational firms (higher CO2 emissions) relocation, from countries with strict environmental regulations to countries with weaker environmental regulations (He, 2006; Wagner and Timmins, 2009). Developing Countries through this channel can be major polluters with the large FDI inflows into these countries.

The trade liberalization arising from removal of barriers can lead countries endowed with abundant natural resources to have comparative advantages in the production of these resources. These comparative advantages give them the power to specialize in pollution-intensive industries. These countries will pollute more with increased openness to international trade (Temurshoev, 2006).. Economic globalization not only contributes to the increase in environmental pollution, it can also lead countries to reduce their polluting gases emission. Indeed, opening to FDI and international trade can be potential opportunities for the less polluting technologies transfer or diffusion, which can lead to efficient production processes in developing countries (Tamazian and Rao, 2010; Leal and Brands, 2019).

The social globalization dimension, which includes the dissemination of ideas, information, images, values and cultures through the NICTs (mobile phones, radios, Internet, WhatsApp and Twitter) and people direct contacts (tourism, migration), either contributes to the increase or decrease in environmental pollution. These channels enable citizens of several countries to exchange information on environmental pollution. However, this information sharing does not necessarily imply changes in citizens' behavior because of the reluctance to espouse foreign cultures and values. Some authors advance the concept of mental or psychological distance to explain the citizens' reluctance to change (Leal and Marques, 2019). The mental distance means

that citizens do not necessarily associate their behavior with environmental problems and sometimes favor consumption over the latter (Rennen and Martens, 2003; Newell *et al.*, 2014). Social globalization can help reduce environmental degradation. Indeed, the information sharing and direct contact between people, allow the population to increase their knowledge regarding the problems associated with the environment deterioration and its protection benefits. Consequently, this population can carry out actions (requirement of clean products consumption, use of less polluting production technologies) directed to the environmental protection (Gawande et al., 2001; Dinda, 2006).

The political globalization, which refers to the government policies dissemination through countries participation in international missions and/or their accession to international institutions, has both negative and positive impact on the environment. The negative effect of political globalization on the environment can be justified by the fact that most international organizations (especially free trade) foresee the limited or inadequate environmental provisions and insufficient guarantees for their application (Liverman *et al*., 1999; Sanchez, 2002). Therefore, countries participation in these organizations does not contribute to the environment improvement. For intense, despite the knowledge of the negative effects of international trade on the environment, the provisions of the WTO and the Kyoto Protocol do not lay down specific targets for environmental degradation (Leal and Marques, 2019). However, the political globalization can have positive effects on the environment. The proliferation of non-governmental organizations (NGOs) and the increasing birth of environmental groups that campaign for environmental protection can guide government actions towards adopting policies against environmental degradation (Lemos and Agrawal, 2006; Paavola, 2007).

Several empirical studies are conducted to examine the relationship between globalization and environmental pollution measured by the CO2 emission and other toxic wastes and gases. A strand of literature analyze the effects of economic globalization on the environment using openness to international trade and FDI. Among the authors analyzing the effects of trade openness on environmental pollution, some find that the openness to trade contributes to environmental degradation (Liddle, 2001; Managi and Kumar, 2009; Le *et al*., 2016; Shahbaz *et al*., 2017; Acheampong *et al*., 2019; Dogan *et al*., 2020). Other authors, on the other hand, show that opening to international trade allows developing countries to acquire clean and less polluting production technologies. Opening to international trade can provide additional income to consumers in developing countries who will demand products that do not harm the environment. Consumers in developed countries are reaffirming their demand for products that allow environmental protection. Through these combined effects, international trade contributes to the reduction of environmental pollution (Antweiler *et al*., 2001; Managi *et al*., 2009; Shahbaz *et al*., 2013; Zhang, 2017; Shahbaz *et al*., 2019).

While testing Kuznets's environmental hypothesis, some authors used the FDI to measure globalization. Among these authors, some find that the FDI contributes to the environment degradation (pollution) in the recipient countries by the toxic gases emission according to the pollution haven hypothesis (Pao and Tsai, 2011; Kivyiro and Arminen, 2014; Aliyu and Ismail, 2015; Behera and Dash, 2017; Solarin and Al-Mulali, 2018; Hanif *et al*., 2019; Shahbaz *et al*., 2019). Other authors, on the other hand, find the environmental improvement effects of the FDI. Indeed, these authors show that the FDI inflow in developing countries is a source of the clean technology diffusion that can contribute to the environment quality (Lee 2013; Mert & Bölük, 2016; Sapkota and Bastola, 2017; Acheampong *et al*., 2019). The last strand of literature uses aggregated indices as the KOF globalization index to investigate the association between globalization and the environment. The intention of these authors is to consider globalization

as whole. Among these authors, some find that globalization as a whole deteriorates the environment by boosting the toxic gases emission (Shahbaz et al., 2017; Shahbaz et al., 2018; Leal and Marques, 2019; Salahuddin et al., 2019). Others believe that globalization as the whole helps to clean up the environment (Shahbaz et al., 2017; Haseeb et al., 2018).

This study examines the effects of globalization on environmental pollution in SSA, and in so doing, it complements the above existing literature. However, our study contributes to the existing literature for several reasons. Firstly, looking to the investigation area, most of the studies carried out in this area have used, to our knowledge only, the FDI and trade openness to analyze the association between globalization and environmental quality. As mentioned above, globalization is not restricted only to these economic indicators. Our study will be comprehensive by considering the three dimensions of globalization using the KOF globalization index. To our knowledge, only the study by Salahuddin *et al*. (2019) carried out in South Africa considered globalization as the whole using the KOF index. Our second contribution, which disentangle between *de jure* and *de facto* aspects of globalization, allows us to surpass the study by Salahuddin *et al*. (2019).

While the *de facto* globalization measures include variables that represent flows and activities, the *de jure* measures include variables that represent economic policies that, in principle, orient flows and activities (Gygli et al., 2019). Some authors claim that this categorization is useful because the decision to use the two aspects measures of globalization can lead to systematically divergent conclusions concerning the effects of globalization on outcome variables including the environment (Quinn et al. 2011). The disentangling between the *de jure* variables and *de facto* is also useful because it enables to judge how economic policies and institutions with regard to globalization can be practical effective. The distinction between the *de jure* and *de facto* aspects of globalization is made by Leal and Marques (2019) in the European Union (EU) countries. However, it remains a contribution for this study since the realities of developed countries (EU for example) are not identical to those of developing countries (SSA for example).

Another aspect is the evolution of globalization in SSA in the recent decades. Two of its dimensions, that is the political and social dimensions, have been very noticeable in SSA countries.. The social globalization has demonstrated on the one hand by the intensification of tourist and migratory flows and on the other hand by the remarkable use of NTCIs (Internet and mobile phone) (Nyirenda-Jere and Biru, 2015; UNWTO, 2017). The political globalization has increased due to the increase in the number of international, non-governmental organizations and conventions to which the SSA belongs or signs. These new trends in globalization raise questions about the revision of its effect on key outcome variables including the environment. This study is also part of this perspective.

The remainder of the paper is organized as follows. Section 2 discusses the methodology, data and estimation strategy. Section 3 presents the results and interpretations and Section 4 concludes.

2. Methodology, Estimation Strategy and Data

2.1 Methodology and Estimation Strategy

To analyze the effects of globalization on environmental pollution in SSA, this paper uses the STRIPAT model (Stochastic Impacts by Regression on Population, Affluence and Technology). This model is commonly used to analyze the determinants of environmental

impact (environmental issues) (Li *et al*., 2011; You and Lv, 2018). The STRIPAT model basic formulation is presented as equation (1):

$$I_{it} = \rho P_{it}^{\theta_1} A_{it}^{\theta_2} T_{it}^{\theta_3} \varepsilon_{it} \quad (1)$$

Where *I* denotes the environmental impact. *P*, *A* and *T* respectively denote population, affluence (ease) and technology. ρ is a constant. θ_i ($i = 1, 2, 3$) are parameters to be estimated. ε is the composite error term. i and t are the individual and time dimension respectively. As equation (1) has multiplicative form, it remains difficult to be estimated. The natural logarithm enables to get the following linear econometric model:

$$lnI_{it} = \alpha + \theta_1 lnP_{it} + \theta_2 lnA_{it} + \theta_3 lnT_{it} + \vartheta_{it} \quad (2)$$

The econometric model (2) explains the environmental impact (pollution or quality) by demographic characteristics (P), economic development (A) and industrial structure (T). Environmental pollution is captured by CO2 emission, the variable commonly used in the environmental framework and whose data are available and easily accessible. The urban population is employed to measure population. Indeed, urban activities are intensive in energy consumption. We can think that the increase in the urban population increases the fossil fuels consumption, which will increase the CO2 emission (Charfeddine, 2017). Economic development is measured by GDP per capita. The industrial structure is measured by industrial added value (You and Lv 2018). As the STRIPAT model offers the flexibility to add economic policy variables, we add our globalization interest variable. After take into consideration the interest variable, other control variables and individual heterogeneities, we get model (3).

$$\ln(CO_{2it}) = \theta_{0i} + \theta_{1i} \ln(urban_{it}) + \theta_{2i} \ln(gdp\_pc_{it}) + \theta_{3i} \ln(indus_{it}) + \theta_{4i} \ln(glob_{it}) + \\ + \theta_{5i} X_{it} + \vartheta_{it} \quad (3)$$

In the model (3) *urban, gdp_pc, indus, glob* and *X* respectively mean the urban population, GDP per capita, industrialization, globalization and other variables that influence the environment pollution. We use fossil fuel consumption as another control variable. Model (3) will be subjected to several panel tests so that to give details on its estimation. We test firstly the cross-sectional (spatial dependence) between the units (countries) studied. This test enables to know if panels are spatially correlated and directs us towards the appropriate panel data tests. Indeed, modern panel data studies propose two kinds of tests (Burdisso and Sangicomo, 2016). To use any type of test will depend to the spatial dependence of the phenomenon between the units studied. Contemporary research using panel data discloses that some unobserved common factors between the units (countries) studied can explain their dependence relationships (Harding *et al*., 2020). For spatial econometrics, the dependence relationships between geographically localized units come from spillover and neighborhood effects (Xu and Lee, 2019). Recent panel models show that the presence of spatial dependence in the panel data leads to biased and inconsistent estimators (Harding *et al*., 2018).

To diagnose the spatial dependence, we use the pre-estimation test by Pesaran (2006). This test has the advantage to test the spatial dependence for each variable included into the regressions unlike the post-estimation test which tests the spatial dependence only in the error term. Indeed, the test computes a spatial dependence statistic (CD-statistic), which under the null hypothesis of spatial independence in the individual dimension, is normally distributed with mean 0 and variance 1. The test implementation rejects the null hypothesis spatial independence between the units studied since the probabilities (p-value) associated with the statistic (CD) are all less

than 1% (see appendix). The presence of spatial dependence undermines the power of first generation panel unit root and cointegration tests, based on independence between the units studied (Westerlund *et al*., 2016; Shariff and Hamzah, 2015). To test the variables unit root, the test by Paseran (2007) will be used. The test has advantage to consider any form of spatial dependence with the possibility to take into account the countries heterogeneous characteristics. The test computes a cross-sectional Im, Peseran Shin (CIPS)' statistic which, under the null hypothesis of unit root is normally distributed with mean 0 and variance 1. The test rejects the null hypothesis of unit root meaning that all variables are stationary at level. Indeed, the variable CIPS-statistics are lower than the critical CIPS proposed at 1%.

We use the estimation approach by Hoechle (2007) to regress the model (3). This approach has advantage to consider the cross-sectional (spatial) dependence as a whole unlike other approaches assume that only some economic and social factors common to the units (countries) can explain their interdependence. Indeed, as mentioned above, the spatial econometrics prove that spatial relationships between units can have their sources in spillover effects through imitation and neighborhood interactions. In addition, the approach has an econometric advantage by overcoming the heteroscedasticity and error autocorrelation problems. It enables considering the individual heterogeneities and obtaining robust standard deviations. For the robustness check, the approach by Park (1967), that is the Feasible Generalized Least Square (FGLS) will be performed.

2.2 Data

To analyze the effect of globalization on environmental pollution, this study uses annual data on 38 countries in Sub-Saharan Africa and over the period from 1980-2017. We selected the countries and period according to the data availability on the variables, which enter our regressions. The environmental literature offers several indicators for assessing quality or environmental pollution, among which one can mention carbon dioxide (CO2), sulfur dioxide (SO2) and nitrogen dioxide (NO2) (see Le *et al*. 2016). However, the most commonly used indicator due to the data availability is CO2. To measure environmental pollution (dependent variable), we use the CO2 emission. This indicator is most accessible in the SSA countries framework. The CO2 emission encompasses the fossil CO2 emissions and expressed in metric tons per year (Mt CO2/year). The data on CO2 emission are gotten from the Emission Database for Global Atmospheric Research Base (EDGAR) for European Union.

To measure the interest variable the study uses the KOF overall globalization index and its sub-indices. The KOF index encompasses all globalization dimensions that is economic, political and social. The index also includes a large panel dataset comprising more than 200 countries and covering the period 1970-2017. These data are easily accessible and may be updated annually. In its recent updated version, the index distinguishes between the *de facto* globalization and the *de jure* globalization. Whether *de jure* or *de facto*, the globalization KOF index is gotten from three sub-indices. The three sub-indices concern the economic, political and social globalization dimensions. Each sub-index is found from several indicators.

The *de facto* economic globalization sub-index includes trade (trade flows as share of GDP) and financial indicators. Financial indicators comprise the sum of stocks of assets and liabilities of foreign direct investment, portfolio investment (as share of GDP) and the sum of primary and cross-border labor and capital income (as share of GDP). The *de facto* social globalization sub-index is obtained by considering interpersonal, informational and cultural indicators. Interpersonal indicators include international voice traffic, international financial transfers, international tourism, and the share of foreign-born people. Informational indicators include the

stock of patent applications filed by non-residents, the sum of incoming and outgoing foreign students, and the export of high-technology products. The cultural indicators embrace the number of McDonald's restaurants, the number of IKEA stores, trade in cultural goods and personal, cultural and recreational services. The *de facto* political globalization sub-index incorporates the number of country' participation in United Nations peacekeeping missions, the number of embassies and NGOs in a country.

The *de jure* economic, political and social globalization sub-indices also stem from some specific indicators. The *de jure* economic globalization sub-index is built using the *de jure* commercial and financial globalization indicators. The *de jure* trade globalization indicators use the average of non-tariff barriers prevalence and procedural costs based on the Doing Business report and the trade taxes measured by income from international trade taxes as share of total income. The *de jure* financial globalization indicators consider the Chinn-Ito index, the Jahan and Wang index (2016), and investment restrictions including the prevalence of foreign ownership and regulation compared to international capital flows. The *de jure* social globalization dimension comes from the *de jure* interpersonal, informational and cultural globalization indicators.

The *de jure* interpersonal globalization indicators use the number of users of fixed and mobile telephones per 100 inhabitants, the number of airports handling international flights and the foreigners' freedom to visit the country. The *de jure* information globalization indicators consider the number of TVs and Internet users per household, the Internet use relevance and press freedom. Finally, *de jure* cultural globalization indicators take into account general government spending on education as a share of GDP, the primary schooling gender parity index and the civil liberty index. The *de jure* political globalization sub-index includes the number of multilateral treaties signed by the country since 1945 and the number of country' membership international organizations. The globalization indices, whether *de jure* or *de facto*, and the sub-indices are scale variables ranging 1 to 100. The value 1 indicates the minimum globalization state and the value 100 indicates the maximum globalization state. The KOF globalization indices are drawn from KOF Swiss Economic Institute (KSEI).

Other regressions variables, namely; GDP per capita, urbanization, industrialization and energy consumption come from the World Development Indicators (WDI) database. Urbanization is measured by the total urban population. Industrialization is captured using industrial value added as a percentage of GDP. Energy consumption relates to fossil fuel consumption as a percentage of total energy consumption. The coefficients associated with these variables are predicted to be positives according to the literature on the determinants of environmental quality (Solarin and Al-Mulali, 2018; Ali *et al*., 2020). Table 1 provides the descriptive statistics and sources of the variables. The explanatory interest variables and CO2 emissions trends are provide in the appendix (The tree figures in the appendix).

Table 1: Variables description and statistic descriptive

Variable	Description	Observation	Average	Minimum	Maximum	Sources
lco_emission	Logarithm of CO2 emission	1444	.67	-2.82	6.19	EDGAR
kofgi	Overall globalization index	1444	40.91	16.94	72.58	KSEI
kofgidf	Overall de facto globalization index	1444	40.85	14.84	72.61	KSEI
kofgidj	Overall de jure globalization index	1444	40.98	14.03	80.83	KSEI
kofecgi	Economic globalization index	1444	41.24	14.68	85.19	KSEI
kofecgidf	Economic de facto globalization index	1444	47.07	10.09	91.42	KSEI
kofecgidj	Economic de jure globalization index	1444	35.35	10.17	81.74	KSEI
kofsogi	Social globalization index	1444	30.91	4.82	77.6	KSEI
kofsogidf	Social de facto globalization index	1444	27.68	5.24	72.14	KSEI
kofsogidj	Social de jure globalization index	1444	34.04	4.39	83.06	KSEI
kofpogi	Political globalization index	1444	50.16	16.41	88.16	KSEI
kofpogidf	Political de facto globalization index	1444	46.87	15.92	93.31	KSEI
kofpogidj	Political de jure globalization index	1444	53.44	8.77	86.03	KSEI
lgdp_pc	Logarithm of GDP per capita	1444	6.5	4.61	9.6	WDI
lpop_urban	Logarithm of urban population	1444	13.75	11.06	16.3	WDI
lindus	Logarithm of industry added value	1444	20.57	16.38	25.66	WDI
energy	Fossil fuel consumption	1444	22.99	0	90.5	WDI

3. Results and Discussion

This section is devoted to the presentation and discussion of the estimation results. Before this task, we will discuss the multicollinearity problem between the interest explanatory variables. The multicollinearity problem is scrutinized employing the Pearson correlation matrix (see appendix). In the most cases, the matrix shows high (greater than 0.5) and significant correlation coefficients. These results demonstrate some presumption of strong correlation between the interest explanatory variables. Indeed, taking together these variables in the same regression will produce the multicollinearity problem that consequences are to affect the estimated coefficients significance. To solve this problem, the estimations are displayed, each incorporating an interest explanatory variable. Furthermore, we paying attention to heteroscedasticity and errors autocorrelation problems. Doing so, we used the Wald's test for heteroscedasticity and Wooldridge's test for errors autocorrelation. The statistics associated with these tests are significant at 1% for all regressions. Therefore, the results confirm the presence of heteroscedasticity and errors autocorrelation. The estimation approaches efficiently overcome these problems.

We now return to the regression results to discuss firstly the overall significance. The three tables of estimations below have the Wald-Chi2 statistics that are high and significant at 1%. This proves that the results of the estimations are globally significant. Table 2 below presents the effects of globalization on CO2 emissions in SSA without distinguishing between the *de jure* and *de facto* aspects. Column (1) shows the effects of the overall globalization while columns (2), (3) and (4) respectively show the effects of the economic, social and political globalization on CO2 emission. Column (5) introduced for the robustness check of the results provides the effects of overall globalization on CO2 emissions. The results of this column are gotten using the Feasible Generalized Least Squares (FGLS) estimation. As can be seen, the coefficients associated with the globalization variables are positive and significant at 1% in the five columns. Indeed the overall globalization and its economic, social and political dimensions positively contribute to the CO2 emissions in SSA. For instance, a one-unit increase in the overall KOF globalization index increases the CO2 emission by about 0.023% (column 1) metric ton (Mt). The same increase for the economic, social and political dimensions respectively increases the CO2 emission by about 0.013%, 0.015% and 0.011% Mt. In column (5) the effect of the overall globalization is positive but weak intensity (0.014) than in column (1). However, more credibility is given to the estimation approach by Hoechle (2007). The latter gives more precision in the presence of spatial dependence.

Table 2: Effects of globalization and its dimensions on CO2 emission

Variables	(1)	(2)	(3)	(4)	(5)
kofgi	0.023***				0.014***
	(0.003)				(0.002)
kofecgi		0.013***			
		(0.002)			
kofsogi			0.015***		
			(0.004)		
kofpogi				0.011***	
				(0.002)	
lgdp_pc	0.213***	0.286***	0.177**	0.249***	0.175***
	(0.062)	(0.056)	(0.086)	(0.057)	(0.024)
lpop_urban	0.345***	0.511***	0.461***	0.432***	0.816***
	(0.083)	(0.067)	(0.094)	(0.078)	(0.042)
lindus	0.057**	0.078**	0.059**	0.072**	-0.014
	(0.027)	(0.029)	(0.028)	(0.030)	(0.013)
energy	0.005***	0.006***	0.006***	0.005***	0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Constant	-7.706***	-10.483***	-8.636***	-9.054***	-12.048***
	(0.797)	(0.493)	(1.170)	(0.611)	(0.601)
Observations	1,336	1,336	1,336	1,336	1,336
Number of countries	38	38	38	38	38
Wald-Chi2	2999***	4383***	1399***	1978***	716.3***
Heteroscedasticity	293.11***	159.37***	196.73***	252.79***	293.11***
Autocorrelation	54.33***	50.83***	51.23***	57.19***	54.33***

Note: ***, ** and * denote the significance at 1%, 5% and 10% respectively. Standard deviations in parentheses. Wald-Chi2 means Wald statistic for overall significance of regressions. Heteroscedasticity means Wald heteroscedasticity test. Autocorrelation means Wooldridge's autocorrelation test.

The effects of the *de jure* globalization and its dimensions are displayed in Table 3. Column (1) of Table 3 shows the overall effects of the *de jure* globalization while columns (2), (3) and (4) respectively assess the effects of the *de jure* economic, social and political globalizations on CO2 emission. Column (5) takes up the estimations from column (1) but with the FGLS approach. As in Table 2, the coefficients of globalization variables are positive and significant at 1%. Admittedly, the improvement in the KOF index of the *de jure* globalization by one unit produces the CO2 emission by about 0.020% Mt. Such improvement for its economic, social and political dimensions increases the CO2 emission by about 0.008%, 0.018% and 0.011% Mt respectively. The robustness check of the results provided in column (5), shows that, with the FGLS the positive effect of the overall *de jure* globalization hold but with a weak intensity (0.008). However, the outcomes gotten by Hoechle (2007) approach are preferred.

Table 3: Effects of *de jure* globalization and its dimensions on CO2 emission

Variables	(1)	(2)	(3)	(4)	(5)
kofgidj	0.020***				0.008***
	(0.002)				(0.002)
kofecgidj		0.008***			
		(0.002)			
kofsogidj			0.018***		
			(0.004)		
kofpogidj				0.011***	
				(0.002)	
lgdp_pc	0.191***	0.246***	0.183**	0.230***	0.161***
	(0.056)	(0.052)	(0.078)	(0.054)	(0.024)
lpop_urban	0.366***	0.567***	0.377***	0.414***	0.856***
	(0.054)	(0.058)	(0.098)	(0.063)	(0.044)
lindus	0.055*	0.093***	0.042	0.068*	-0.013
	(0.032)	(0.032)	(0.028)	(0.034)	(0.014)
energy	0.006***	0.006***	0.007***	0.005**	0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Constant	-7.712***	-11.081***	-7.340***	-8.608***	-12.275***
	(0.629)	(0.437)	(1.237)	(0.681)	(0.625)
Observations	1,336	1,336	1,336	1,336	1,336
Number of countries	38	38	38	38	38
Wald-Chi2	3826***	4585***	1800***	2374***	662.3***
Heteroscedasticity	312.50***	266.11***	244.11***	508.58***	312.50***
Autocorrelation	53.59***	53.42***	53.27***	54.07***	53.59***

Note: ***, ** and * denote the significance at 1%, 5% and 10% respectively. Standard deviations in parentheses. Wald-Chi2 means Wald statistic for overall significance of regressions. Heteroscedasticity means Wald heteroscedasticity test. Autocorrelation means Wooldridge's autocorrelation test.

Table 4 discusses the effects of the *de facto* globalization and its dimensions on CO2 emissions in SSA. Column (1) shows the *de facto* globalization effects as the whole while columns (2), (3) and (4) respectively set out the effects of the economic, social and political dimensions of the *de facto* globalization. The coefficients linked to the *de facto* globalization and its economic and political dimensions are positive and significant at 1% (columns 1, 2 and 5) and 5% (column 4). The coefficient of the *de facto* social globalization variable is positive but insignificant. The *de facto* globalization, its economic and political dimensions affect positively the environmental pollution in SSA. Indeed, when the SSA countries boost their KOF index of the *de facto* globalization by 1 point, the CO2 emission increase by around 0.012 Mt percentage point (column 1). The same strengthening for its economic and political dimensions produces the CO2 emission by around 0.007% and 0.004% Mt respectively.

Table 4: Effects of *de facto* globalization and its dimensions on CO2 emission

Variables	(1)	(2)	(3)	(4)	(5)
kofgidf	0.012***				0.009***
	(0.004)				(0.002)
kofecgidf		0.007***			
		(0.002)			
kofsogidf			0.005		
			(0.003)		
kofpogidf				0.004**	
				(0.002)	
lgdp_pc	0.258***	0.308***	0.234***	0.278***	0.190***
	(0.062)	(0.057)	(0.077)	(0.060)	(0.024)
lpop_urban	0.476***	0.533***	0.577***	0.564***	0.848***
	(0.108)	(0.084)	(0.083)	(0.081)	(0.042)
lindus	0.081***	0.079***	0.087***	0.081**	-0.011
	(0.027)	(0.029)	(0.030)	(0.030)	(0.014)
energy	0.005***	0.006***	0.006***	0.006***	0.004***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Constant	-9.830***	-10.762***	-10.841***	-10.881***	-12.406***
	(0.903)	(0.593)	(0.781)	(0.564)	(0.605)
Observations	1,336	1,336	1,336	1,336	1,336
Number of countries	38	38	38	38	38
Wald-Chi2	2416***	3211***	1805***	1765***	673.8***
Heteroscedasticity	250.35***	190.70***	244.11***	143.50***	250.35***
Autocorrelation	54.25***	50.65***	50.89***	55.90***	54.25***

Note: ***, ** and * denote the significance at 1%, 5% and 10% respectively. Standard deviations in parentheses. Wald-Chi2 means Wald statistic for overall significance of regressions. Heteroscedasticity means Wald heteroscedasticity test. Autocorrelation means Wooldridge's autocorrelation test.

We now examine the homogeneity effects of the *de jure* and *de facto* globalization aspects on the CO2 emission. The main motivation is whether the regulations (laws and decrees) that govern globalization remain harmonious with its implementation concerning the effects on the CO2 emission. Whether there are some coherences between the both globalization aspects effects, the globalization coefficients in Tables 3 and 4 would be more similar. This is not the case when looking at the two tables. The coefficients of the *de facto* globalization variables are relatively lower than the *de jure* globalization variables ones. These discrepancies could stem from the methodological shifts. One can also set forth the deficiencies in the monitoring of the implementation of the regulations governing globalization to explain such discrepancies. The lack of conformity may also support the assertion that the decision to use the *de facto* or *de jure* measures of globalization may lead to different outcomes.

It seems clearly that, the globalization as the whole and its *de jure* and *de facto* aspects increase the environmental pollution in SSA. These outcomes corroborate with the recent studies carried out in this field such as Salahuddin et al. (2019), Leal et al. (2019), Shahbaz et al. (2018). However, the effects (coefficients) magnitude differs slightly since our estimation coefficients are slightly lower than those of the above authors. This slight difference may be due to the methodological approaches and countries embody in the samples. Our results support the theories that support the environmental degradation hypothesis of globalization. We move now to the control variables. The coefficients of the control variables have their expected signs in the most cases. The coefficients of these variables are positive and significant at 1%, 5% or 10% in the most cases. Indeed, the enhancement of the economic growth, industrialization and urbanization, and the fossil energy consumption are likely to speed up the CO2 emission.

4. Conclusion and recommendations

The paper aims to analyze the effects of globalization on environmental pollution in SSA by disentangling between the *de jure* and *de facto* globalization aspects. The study focus on 38 countries over the period from 1980 to 2017. The study uses the second generation panel data tests to test the spatial dependence and unit root of the variables. The estimation approach by Hoechle (2007) is used to overcome the problems of the spatial dependence, heteroscedasticity and errors autocorrelation. For the robustness check, the FGLS estimation is performed. The results show that the globalization and its *de jure* and *de facto* aspects contribute to the environment degradation in SSA by hastening the CO2 emissions. When creating the globalization policies, the policymakers must focus on the measures that hearten the renewable energies use, which is found to be less polluting. They must also consider in their regulations governing globalization, trade and foreign direct investment policies aimed at the clean technologies importation and the ban of the more polluting multinational firms in their countries. To export natural resources (especially hydrocarbons), countries must use the clean methods for their exploitation so that to prevent these resources to become the sources of the environmental degradation. These actions enable to reduce the environmental pollution and establish sustainable development.

References

Acheampong, A.O., Adams, S. & Boateng, E., 2019. Do globalization and renewable energy contribute to carbon emissions mitigation in Sub-Saharan Africa? *Science of The Total Environment*, 677, pp.436–446. Available at: http://dx.doi.org/10.1016/j.scitotenv.2019.04.353.

Ali, S. et al., 2020. Dynamic common correlated effects of trade openness, FDI, and institutional performance on environmental quality: evidence from OIC countries. *Environmental Science and Pollution Research*, 27(11), pp.11671–11682. Available at: http://dx.doi.org/10.1007/s11356-020-07768-7.

Aliyu, A. J., & Ismail, N. W., 2015. Foreign direct investment and pollution haven: does energy consumption matter in African countries?. *International Journal of Economics and Management*, *9*(2015), 21-23.

Antweiler, W., Copeland, B.R. & Taylor, M.S., 2001. Is Free Trade Good for the Environment? *American Economic Review*, 91(4), pp.877–908. Available at: http://dx.doi.org/10.1257/aer.91.4.877.

Autant-Bernard, C. & LeSage, J.P., 2011. Quantifying knowledge spillovers using spatial econometric models. *Journal of Regional Science*, 51(3), pp.471–496. Available at: http://dx.doi.org/10.1111/j.1467-9787.2010.00705.x.

Baliamoune-Lutz, M., 2006. Globalisation and Gender Inequality: Is Africa Different? *Journal of African Economies*, 16(2), pp.301–348. Available at: http://dx.doi.org/10.1093/jae/ejl037.

BATAKA, H., 2019. De jure, De facto Globalization and Economic Growth in Sub-Saharan Africa. *Journal of Economic Integration*, 34(1), pp.133–158. Available at: http://dx.doi.org/10.11130/jei.2019.34.1.133.

BATAKA, H., 2020. Globalization and Gender Inequalities in Sub-Saharan Africa. *The International Trade Journal*, 34(6), pp.516–534. Available at: http://dx.doi.org/10.1080/08853908.2020.1774448.

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, pp.96–106. Available at: http://dx.doi.org/10.1016/j.rser.2016.11.201.

Burdisso, T. & Sangiácomo, M., 2016. Panel Time Series: Review of the Methodological Evolution. *The Stata Journal*, 16(2), pp.424–442. Available at: http://dx.doi.org/10.1177/1536867x1601600210.

Charfeddine, L., 2017. The impact of energy consumption and economic development on Ecological Footprint and CO2 emissions: Evidence from a Markov Switching Equilibrium Correction Model. *Energy Economics*, 65, pp.355–374. Available at: http://dx.doi.org/10.1016/j.eneco.2017.05.009.

Dinda, S., 2006. Globalization and environment: can pollution haven hypothesis alone explain the impact of globalization on environment?.

Dogan, B. et al., 2020. Impacts of export quality on environmental degradation: does income matter? *Environmental Science and Pollution Research*, 27(12), pp.13735–13772. Available at: http://dx.doi.org/10.1007/s11356-019-07371-5.

Egbetunde, T. & Akinlo, A.E., 2015. Financial Globalization and Economic Growth in Sub-Saharan Africa: Evidence from Panel Cointegration Tests. *African Development Review*, 27(3), pp.187–198. Available at: http://dx.doi.org/10.1111/1467-8268.12140.

Gawande, K., Berrens, R. P., & Bohara, A. K., 2001. A consumption-based theory of the environmental Kuznets curve. *Ecological economics*, 37(1), pp.101-112.

Gygli, S. et al., 2019. The KOF Globalisation Index – revisited. The Review of International Organizations, 14(3), pp.543–574. Available at: http://dx.doi.org/10.1007/s11558-019-09344-2.

Hanif, I. et al., 2019. Fossil fuels, foreign direct investment, and economic growth have triggered CO2 emissions in emerging Asian economies: Some empirical evidence. *Energy*, 171, pp.493–501. Available at: http://dx.doi.org/10.1016/j.energy.2019.01.011.

Harbine, J., 2002. NAFTA Chapter 11 arbitration: Deciding the price of free trade. *Ecology law quarterly*, 371-394.

Harding, M., Lamarche, C. & Pesaran, M.H., 2020. Common correlated effects estimation of heterogeneous dynamic panel quantile regression models. *Journal of Applied Econometrics*, 35(3), pp.294–314. Available at: http://dx.doi.org/10.1002/jae.2753.

Haseeb, A. et al., 2018. Financial development, globalization, and CO2 emission in the presence of EKC: evidence from BRICS countries. *Environmental Science and Pollution Research*, 25(31), pp.31283–31296. Available at: http://dx.doi.org/10.1007/s11356-018-3034-7.

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

Jin, Y. et al., 2017. Effects of environmental pollutants on gut microbiota. *Environmental Pollution*, 222, pp.1–9. Available at: http://dx.doi.org/10.1016/j.envpol.2016.11.045.

Kampa, M. & Castanas, E., 2008. Human health effects of air pollution. *Environmental Pollution*, 151(2), pp.362–367. Available at: http://dx.doi.org/10.1016/j.envpol.2007.06.012.

Kivyiro, P. & Arminen, H., 2014. Carbon dioxide emissions, energy consumption, economic growth, and foreign direct investment: Causality analysis for Sub-Saharan Africa. *Energy*, 74, pp.595–606. Available at: http://dx.doi.org/10.1016/j.energy.2014.07.025.

Le, T.-H., Chang, Y. & Park, D., 2016. Trade openness and environmental quality: International evidence. *Energy Policy*, 92, pp.45–55. Available at: http://dx.doi.org/10.1016/j.enpol.2016.01.030.

Leal, P. H. & Marques, A. C., 2019. Are de jure and de facto globalization undermining the environment? Evidence from high and low globalized EU countries. *Journal of Environmental Management*, 250, p.109460. Available at: http://dx.doi.org/10.1016/j.jenvman.2019.109460.

Lee, J.W., 2013. The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth. *Energy Policy*, 55, pp.483–489. Available at: http://dx.doi.org/10.1016/j.enpol.2012.12.039.

Lee, H. & Roland-Holst, D., 1997. The environment and welfare implications of trade and tax policy. *Journal of Development Economics*, 52(1), pp.65–82. Available at: http://dx.doi.org/10.1016/s0304-3878(96)00439-7.

Lemos, M.C. & Agrawal, A., 2006. Environmental Governance. *Annual Review of Environment and Resources*, 31(1), pp.297–325. Available at: http://dx.doi.org/10.1146/annurev.energy.31.042605.135621.

Li, H., Mu, H., Zhang, M., & Li, N., 2011. Analysis on influence factors of China's CO2 emissions based on Path–STIRPAT model. *Energy Policy*, 39(11), pp.6906-6911. Available at: https://doi.org/10.1016/j.enpol.2011.08.056.

Liddle, B., 2001. Free trade and the environment-development system. *Ecological Economics*, 39(1), pp.21–36. Available at: http://dx.doi.org/10.1016/s0921-8009(01)00215-4.

Liverman, D. M., Varady, R. G., Chávez, O., & Sánchez, R. (1999). Environmental issues along the United States-Mexico border: Drivers of change and responses of citizens and institutions. *Annual Review of Energy and the Environment*, 24(1), pp.607-643. Available at: https://doi.org/10.1146/annurev.energy.24.1.607.

Majidi, A.F., 2017. Globalization and Economic Growth: The Case Study of Developing Countries. *Asian Economic and Financial Review*, 7(6), pp.589–599. Available at: http://dx.doi.org/10.18488/journal.aefr.2017.76.589.599.

Managi, S. & Kumar, S., 2009. Trade-induced technological change: Analyzing economic and environmental outcomes. *Economic Modelling*, 26(3), pp.721–732. Available at: http://dx.doi.org/10.1016/j.econmod.2009.02.002.

Managi, S., Hibiki, A. & Tsurumi, T., 2009. Does trade openness improve environmental quality? *Journal of Environmental Economics and Management*, 58(3), pp.346–363. Available at: http://dx.doi.org/10.1016/j.jeem.2009.04.008.

Mert, M. & Bölük, G., 2016. Do foreign direct investment and renewable energy consumption affect the CO2 emissions? New evidence from a panel ARDL approach to Kyoto Annex countries. *Environmental Science and Pollution Research*, 23(21), pp.21669–21681. Available at: http://dx.doi.org/10.1007/s11356-016-7413-7.

Motoshita, M. et al., 2015. Potential impacts of information disclosure designed to motivate Japanese consumers to reduce carbon dioxide emissions on choice of shopping method for daily foods and drinks. *Journal of Cleaner Production*, 101, pp.205–214. Available at: http://dx.doi.org/10.1016/j.jclepro.2015.04.005.

Newell, B.R. et al., 2014. The Psychology of Environmental Decisions. *Annual Review of Environment and Resources*, 39(1), pp.443–467. Available at: http://dx.doi.org/10.1146/annurev-environ-010713-094623.

Nowak, D.J. et al., 2014. Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, 193, pp.119–129. Available at: http://dx.doi.org/10.1016/j.envpol.2014.05.028.

Nyirenda-Jere, T., & Biru, T., 2015. Internet development and Internet governance in Africa. *ISOC Report, 17-53*.

Paavola, J., 2007. Institutions and environmental governance: A reconceptualization. *Ecological Economics*, 63(1), pp.93–103. Available at: http://dx.doi.org/10.1016/j.ecolecon.2006.09.026.

Pao, H.-T. & Tsai, C.-M., 2011. Multivariate Granger causality between CO2 emissions, energy consumption, FDI and GDP: Evidence from a panel of BRIC countries. *Energy*, 36(1), pp.685–693. Available at: http://dx.doi.org/10.1016/j.energy.2010.09.041.

Pesaran, M.H., 2006. Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure. *Econometrica*, 74(4), pp.967–1012. Available at: http://dx.doi.org/10.1111/j.1468-0262.2006.00692.x.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2), pp.265–312. Available at: http://dx.doi.org/10.1002/jae.951.

Quinn, D., Schindler, M. & Toyoda, A.M., 2011. Assessing Measures of Financial Openness and Integration. *IMF Economic Review*, 59(3), pp.488–522. Available at: http://dx.doi.org/10.1057/imfer.2011.18.

Rennen, W. & Martens, P., 2003. The Globalization Timeline. *Integrated Assessment*, 4(3), pp.137–144. Available at: http://dx.doi.org/10.1076/iaij.4.3.137.23768.

Salahuddin, M. et al., 2019. Urbanization-globalization-CO2 emissions nexus revisited: empirical evidence from South Africa. *Heliyon*, 5(6), p.e01974. Available at: http://dx.doi.org/10.1016/j.heliyon.2019.e01974.

SANCHEZ, R.A., 2002. Governance, Trade, and the Environment in the Context of NAFTA. *American Behavioral Scientist*, 45(9), pp.1369–1393. Available at: http://dx.doi.org/10.1177/0002764202045009005.

Sapkota, P. & Bastola, U., 2017. Foreign direct investment, income, and environmental pollution in developing countries: Panel data analysis of Latin America. *Energy Economics*, 64, pp.206–212. Available at: http://dx.doi.org/10.1016/j.eneco.2017.04.001.

Shariff, N.S.M. & Hamzah, N.A., 2015. A Robust Panel Unit Root Test in the Presence of Cross Sectional Dependence. *Journal of Modern Applied Statistical Methods*, 14(2), pp.159–171. Available at: http://dx.doi.org/10.22237/jmasm/1446351180.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., & Leitão, N. C., 2013. Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia.

Renewable and Sustainable Energy Reviews, 25, pp.109–121. Available at: http://dx.doi.org/10.1016/j.rser.2013.04.009.

Shahbaz, M., Nasreen, S., Ahmed, K., & Hammoudeh, S., 2017. Trade openness–carbon emissions nexus: The importance of turning points of trade openness for country panels. *Energy Economics*, 61, pp.221–232. Available at: http://dx.doi.org/10.1016/j.eneco.2016.11.008.

Shahbaz, M., Bhattacharya, M. & Ahmed, K., 2017. CO2 emissions in Australia: economic and non-economic drivers in the long-run. *Applied Economics*, 49(13), pp.1273–1286. Available at: http://dx.doi.org/10.1080/00036846.2016.1217306.

Shahbaz, M., Khan, S., Ali, A., & Bhattacharya, M., 2017. The impact of globalization on CO2 emissions in China. *The Singapore Economic Review*, 62(04), pp.929–957. Available at: http://dx.doi.org/10.1142/s0217590817400331.

Shahbaz, M., Shahzad, S. J. H., Mahalik, M. K., & Hammoudeh, S., 2017. Does Globalization Worsen Environmental Quality in Developed Economies? *Environmental Modeling & Assessment*, 23(2), pp.141–156. Available at: http://dx.doi.org/10.1007/s10666-017-9574-2.

Shahbaz, M., Gozgor, G., Adom, P. K., & Hammoudeh, S., 2019. The technical decomposition of carbon emissions and the concerns about FDI and trade openness effects in the United States. *International Economics*, 159, pp.56–73. Available at: http://dx.doi.org/10.1016/j.inteco.2019.05.001.

Solarin, S.A. & Al-Mulali, U., 2018. Influence of foreign direct investment on indicators of environmental degradation. *Environmental Science and Pollution Research*, 25(25), pp.24845–24859. Available at: http://dx.doi.org/10.1007/s11356-018-2562-5.

Tamazian, A. & Bhaskara Rao, B., 2010. Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Economics*, 32(1), pp.137–145. Available at: http://dx.doi.org/10.1016/j.eneco.2009.04.004.

Temurshoev, U., 2006. Pollution Haven Hypothesis or Factor Endowment Hypothesis: Theory and Empirical Examination for the US and China. *SSRN Electronic Journal*. Available at: http://dx.doi.org/10.2139/ssrn.1147660.

UNWTO (United Nation World Tourism Organization), 2017. UNWTO Tourism Highlights. http://people.unica.it/carlamassidda/files/2017/06/UNWTO_Tourism-Highlights_2017.pdf.

Wagner, U.J. & Timmins, C.D., 2008. Agglomeration Effects in Foreign Direct Investment and the Pollution Haven Hypothesis. *Environmental and Resource Economics*, 43(2), pp.231–256. Available at: http://dx.doi.org/10.1007/s10640-008-9236-6.

Westerlund, J., Hosseinkouchack, M. & Solberger, M., 2014. The Local Power of the CADF and CIPS Panel Unit Root Tests. *Econometric Reviews*, 35(5), pp.845–870. Available at: http://dx.doi.org/10.1080/07474938.2014.977077.

Xu, X. & Lee, L., 2019. Theoretical foundations for spatial econometric research. *Regional Science and Urban Economics*, 76, pp.2–12. Available at: http://dx.doi.org/10.1016/j.regsciurbeco.2018.04.002.

You, W. & Lv, Z., 2018. Spillover effects of economic globalization on CO2 emissions: A spatial panel approach. *Energy Economics*, 73, pp.248–257. Available at: http://dx.doi.org/10.1016/j.eneco.2018.05.016.

Zahonogo, P., 2017. Globalization and Economic Growth in Developing Countries: Evidence from Sub-Saharan Africa. *The International Trade Journal*, 32(2), pp.189–208. Available at: http://dx.doi.org/10.1080/08853908.2017.1333933.

Zhang, S., Liu, X. & Bae, J., 2017. Does trade openness affect CO2 emissions: evidence from ten newly industrialized countries? *Environmental Science and Pollution Research*, 24(21), pp.17616–17625. Available at: http://dx.doi.org/10.1007/s11356-017-9392-8.

Appendix

Table 5: Cross-sectional (spatial) dependence and unit root tests

Variables	Pesaran (2006) spatial dependence test		Pesaran (2007) Unit root test	
	CD	Correlation	CIPS-statistic	Critical CIPS at 1%
Kofgi	152.43***	0.933	-5.762***	-2.72
kofgidf	112.22***	0.687	-5.892***	-2.72
kofgidj	155.89***	0.954	-5.611***	-2.72
kofecgi	55.41***	0.339	-5.822***	-2.72
kofecgidf	24.29***	0.149	-5.802***	-2.72
kofecgidj	33.27***	0.204	-5.471***	-2.72
kofsogi	157.69***	0.965	-5.471***	-2.72
kofsogidf	149.69***	0.916	-5.166***	-2.72
kofsogidj	154.38***	0.945	-5.534***	-2.72
kofpogi	139.01***	0.851	-5.564***	-2.72
kofpogidf	71.63***	0.438	-5.661***	-2.72
kofpogidj	151.05***	0.924	-5.518***	-2.72
lco_emission	91.91***	0.586	-5.783***	-2.72
lgdp_pc	106.13***	0.678	-5.601***	-2.72
lpop_urban	151.62***	0.968	-4.805***	-2.72
Lindus	113.95***	0.697	-5.736***	-2.72
energy	.	.	-3.438***	-2.72

Note: ***, ** and * denote the significance at 1%, 5% and 10% respectively.

Table 6: Countries in the sample studied

Angola	Mali
Benin	Mauritania
Botswana	Mauritius
Burkina Faso	Mozambique
Burundi	Namibia
Cameroon	Niger
Chad	Nigeria
Republic of Congo	Rwanda
Cote d'Ivoire	Senegal
Ethiopia	Seychelles
Gabon	Sierra Leone
Gambia	South Africa
Ghana	Sudan
Guinea	Swaziland
Kenya	Tanzania
Lesotho	Togo
Liberia	Uganda
Madagascar	Zambia
Malawi	Zimbabwe

Table 7: Correlation matrix

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) lco_emission	1.000												
(2) kofgi	0.459***	1.000											
(3) kofgidf	0.465***	0.922***	1.000										
(4) kofgidj	0.382***	0.924***	0.704***	1.000									
(5) kofecgi	0.112***	0.748***	0.740***	0.643***	1.000								
(6) kofecgidf	-0.016	0.583***	0.708***	0.372***	0.894***	1.000							
(7) kofecgidj	0.266***	0.664***	0.451***	0.774***	0.706***	0.315***	1.000						
(8) kofsogi	0.204***	0.812***	0.779***	0.719***	0.701***	0.609***	0.524***	1.000					
(9) kofsogidf	0.184***	0.723***	0.742***	0.592***	0.655***	0.607***	0.430***	0.958***	1.000				
(10) kofsogidj	0.209***	0.836***	0.758***	0.783***	0.697***	0.570***	0.578***	0.967***	0.854***	1.000			
(11) kofpogi	0.604***	0.590***	0.479***	0.609***	0.037	-0.117***	0.264***	0.094***	-0.005	0.175***	1.000		
(12) kofpogidf	0.664***	0.477***	0.480***	0.400***	-0.049*	-0.169***	0.165***	0.040	-0.055**	0.123***	0.905***	1.000	
(13) kofpogidj	0.381***	0.577***	0.358***	0.706***	0.130***	-0.027	0.317***	0.135***	0.055**	0.193***	0.863***	0.565***	1.000

Note: ***, ** and * denote the significance at 1%, 5% and 10% respectively.

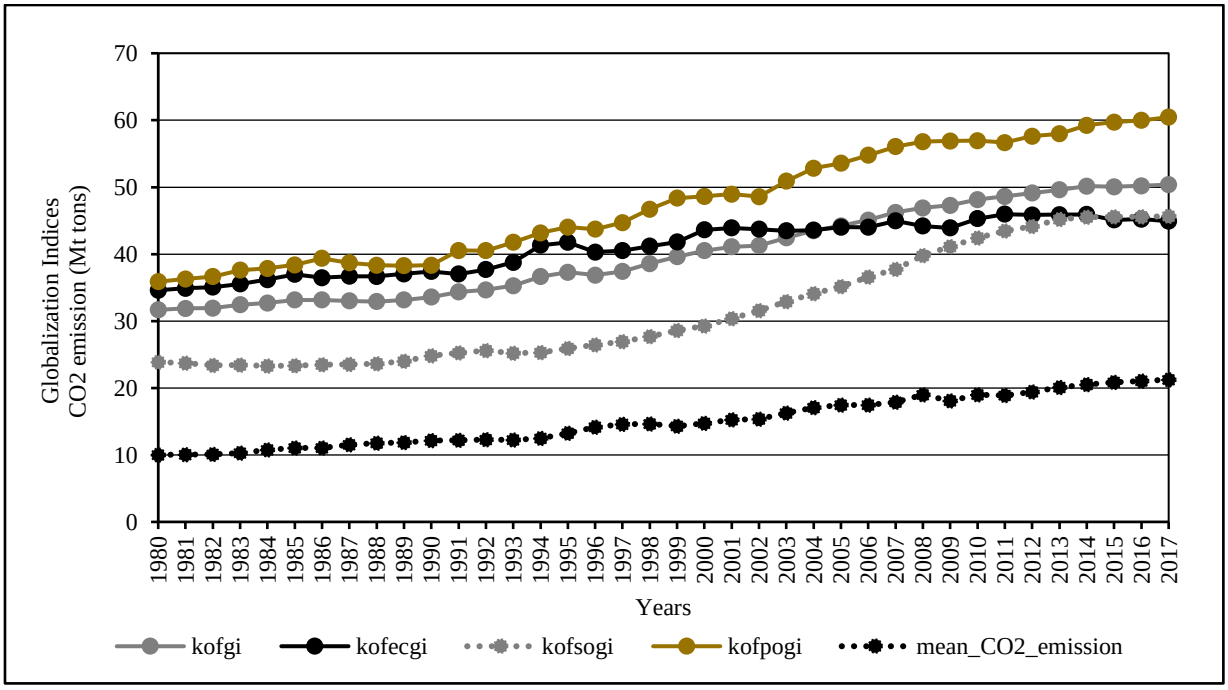

Figure 1: Trends of Globalization indices and CO2 emission

Source: Author construction based on the data from KSEI and EDGAR.

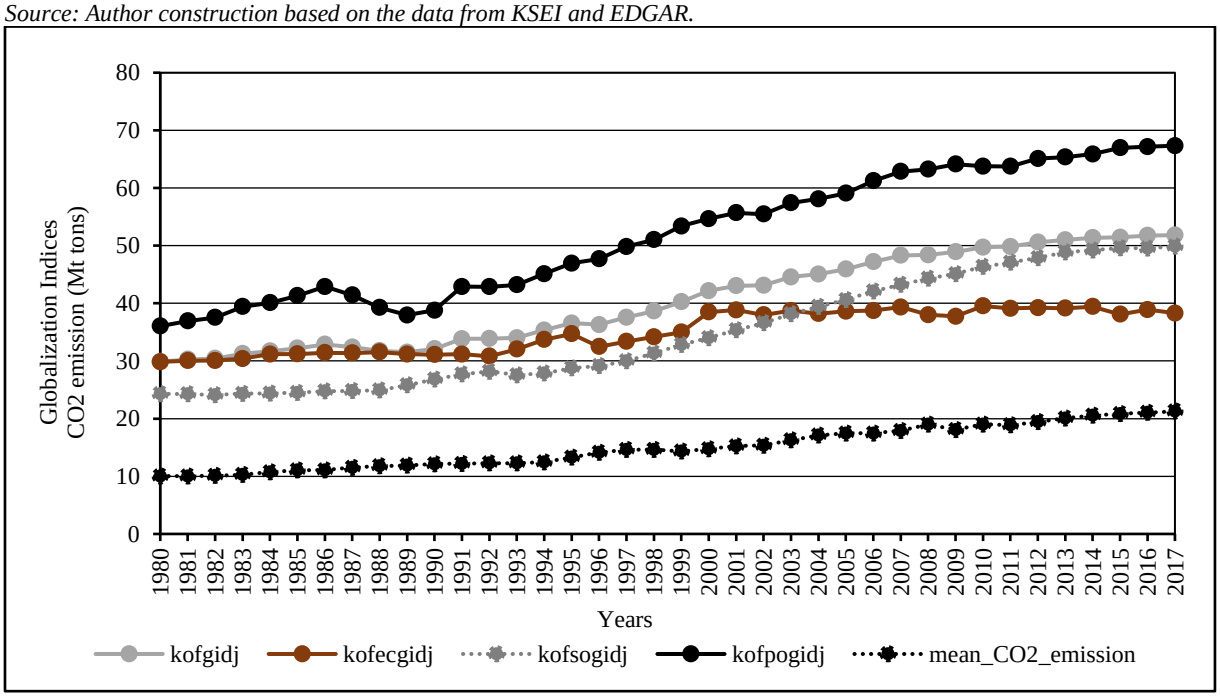

Figure 2: Trends of de jure globalization indices and CO2 emission

Source: Author construction based on the data from KSEI and EDGAR.

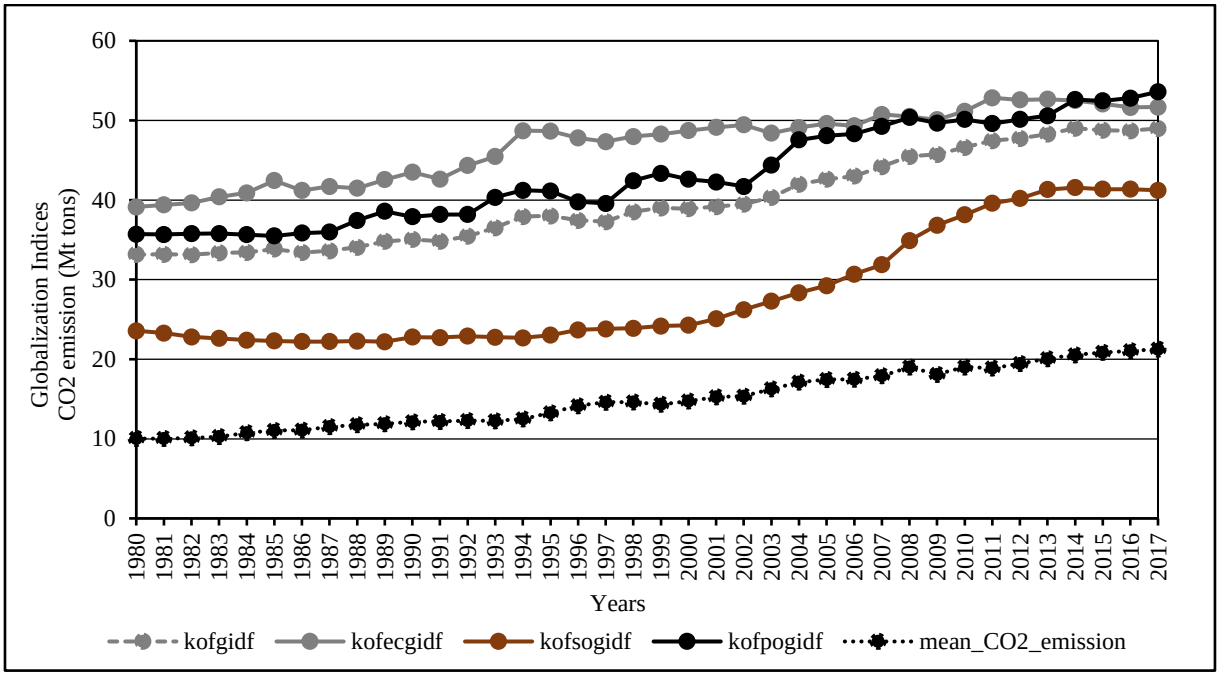

Figure 3: Trends of de facto globalization indices and CO2 emission

Source: Author construction based on the data from KSEI and EDGAR.