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## Article

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# The nexus between human development, official development assistance, carbon emissions, and governance in developing countries for the realization of sustainable development goals

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## ABSTRACT

The paper aims to analyze human development through its interactions with environmental protection, governance, and official development assistance (ODA) in developing countries. This is done to allow the decision-makers of the latter to have an optimal approach to sustainable development goals (SDGs). For this matter, we used data from 56 developing countries for the period from 2005 to 2019 with the novel cross-sectionally augmented ARDL and augmented mean group (AMG). Interactive terms have been used for robustness checks. The results showed that, for low-income countries, ODA harms human development while governance effectiveness has a positive impact. The combination of governance effectiveness and ODA has a positive impact on human development. The same positive impact is found for the combination of governance and carbon emissions on human development. For middle-income countries, the findings showed that carbon emissions have a positive impact on human development. The combination of carbon emissions and ODA has a positive impact on human development. We recommend that; first, low-income countries' policymakers focus on the achievement of the combination of SDG 16 and SDG 17 with SDG 16 as the central piece for SDGs realization; Second, middle-income countries' policymakers focus on the achievement of the combination of SDG 8, SDG 16, and SDG 17 with SDG 8 as the central piece for SDGs realization. ODA donors must consider the needs of the countries receiving assistance and ease the conditions for obtaining aid. Moreover, we recommend collaboration focused on technology transfer between developed and developing countries.

## IMPACT STATEMENT

In recent years, the achievement of sustainable development goals has been the aim of many countries. Human development, linked with many sustainable development goals, plays a central role. Moreover, the current context of climate change is taking on a planetary scale, forcing all the governments of the world to consider only development that guarantees the protection of the environment. The 2030 agenda for pursuing sustainable development requires cooperation between all countries of the world while paying particular attention to the developing country. Thus, the objective of this paper is to analyze human development through its interactions with environmental protection, governance, and development assistance in developing countries. This is done to allow the decision-makers of the latter to have an optimal approach to development but also to allow their partners a better allocation of their assistance. For this matter, data for 56 developing countries for the period from 2005 to 2019 with the novel cross-section ARDL and augmented mean group (AMG) were used. Interactive terms have been used for robustness checks. The results showed that, for low-income countries, ODA harms human development while governance effectiveness has a positive impact. The combination of governance effectiveness and ODA has a positive impact on human development. The same positive impact is found for the combination of governance and carbon emissions on human development. For middle-income countries, the findings showed that carbon emissions have a positive impact on human development. The combination of carbon emissions and ODA has a positive impact on human development. For low-income countries, in regards of the positive impact of governance effectiveness on human development, we recommend

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that decision-makers prioritize the achievement of SDG 16 “peace, justice and strong institutions” and use this objective as a central piece in the achievement of other SDGs, particularly by fighting corruption in all its forms. We recommend as a priority an analysis of the real needs of every country considering its factor endowment not only for the elaboration of good policies but also for the optimal allocation of resources with the aim of achieving SDG 8 “decent work and economic growth”. moreover, low-income countries need cooperation with other countries, reflecting the importance of SDG 17 “partnerships for the goals”. For middle-income countries, carbon emissions, characterizing an increase in economic activity, constitute an important indicator of economic growth and the realisation of SDG 8 “decent work and economic growth”. We recommend that policymakers of middle-income countries focus on the realization of SDG 8 “decent work and economic growth” and use this objective as a central piece in the achievement of other SDGs for human development. Moreover, we recommend to decision-makers in these countries the association of SDG 8 and SDG 17 “partnerships for the goals” (materializing international cooperation) to further optimize human development.

## 1. Introduction

Since the adoption of the SDGs (Sustainable Development Goals) in 2015 by the state members of the United Nations during a General Assembly, one of the objectives of countries has been to achieve sustained economic growth to enable human development. However, it's paramount to shed light on the difference between human development and economic growth. While economic growth refers to a quantitative change in output, human development refers to a qualitative change in society through social and economic progress Nino (2015). Given the complexity of measuring development, UNDP (United Nations Development Program) developed the Human Development Index (HDI) based on three dimensions: income, education, and health. This index is directly related to SDG 1 ‘no poverty’, SDG 8 ‘decent work and economic growth’ through its dimension on income level. HDI is directly related to SDG 3 ‘good health and well-being’ through its dimension on well-being but also directly related to SDG 4 ‘quality education’ through its dimension on education. Moreover, the HDI is indirectly related to SDG 2 ‘zero hunger’ and SDG 10 ‘reduced inequalities’. The links between this indicator and SDGs emphasize the central role it plays in the development process. Thus, if the HDI is moving in the right direction, it is rather likely that those SDGs are progressing too.

Furthermore, given the importance of achieving the SDGs, environmental protection plays a major role in human well-being. The protection of ecosystems, linked to several of the SDGs in particular goal 6 ‘clean water and sanitation’, goal 7 “affordable and clean energy”, goal 13 “climate action”, and goal 14 “life below water”, is one of the major objectives for human development. Through the Paris agreement, ratified by 186 parties in 2019, carbon emissions need to fall by a staggering 45% by 2030 from 2010 levels. Furthermore, achieving these climate and human development objectives requires effective and efficient government action, and thus the realization of goal 16 ‘peace, justice and strong institutions’. However, for developing countries, the achievement of the SDGs requires significant financial support, and thus the realization of goal 17 ‘partnerships for the goals’. This assistance is provided through official development assistance (ODA). However, the effectiveness of ODA remains mitigated, which brings to the fore the importance of good management and good direction of this aid. This is why the analysis of the interactions between the Human Development Index (HDI), carbon emissions, governance, and ODA is of capital importance for developing countries in the achievement of the SDGs.

In the literature, the environmental Kuznet curve (EKC) Grossman and Krueger (1991), who put forward the relationship between environmental pollution and economic growth, has engendered debate regarding the mixed findings. This EKC hypothesis, which shows how to achieve economic development without compromising environmental quality, plays a central role in the realization of SDGs. In the last few decades, fossil fuels have contributed to economic progress but at the cost of environmental degradation. For Akalpler and Hove (2019), further economic development will lead to ecological degradation due to the use of unsafe products resulting in demographic, health, and social concerns. As suggested by Baloch et al. (2020) reducing poverty is the priority of the SDGs agenda. However, Goldstein (2015) showed that countries that have dramatically reduced poverty have in turn increased

carbon emissions while countries that have faced a rise in poverty have also experienced a decrease in carbon emissions. Furthermore, excessive use of fossil fuels leading to an increase in CO<sub>2</sub> emissions harms the world climate and exposes more people to poverty Alola et al. (2019); Crentsil et al. (2019). The EKC hypothesis showed that it is possible to associate economic growth and environmental improvements if we put in place the appropriate policies mixed with a certain level of technology Grossman and Krueger (1991). However, Du (2007) suggested that a change in lifestyle and consumption modes is essential to energy conservation and emission reduction other than technological progress.

However, to ensure low-carbon economic development in all countries, developed countries, and international organizations have been providing ODA (Official Development Assistance) to developing countries to meet SDGs as the development process requires consequent financing. Official development assistance (ODA), according to the Development Assistance Committee (DAC) of the OECD (The Organization for Economic Cooperation and Development), is defined as aid provided by States for the express purpose of promoting economic development and improving living conditions in developing countries Hynes and Scott (2013). According to the literature, this aid can have a positive impact on development through its effect on education, health, and income Shirazi et al. (2010); Shon et al. (2018) but can also harm total factor productivity which in the long term leads to development Groß and Nowak-Lehmann Danzinger (2022). For C. Burnside and Dollar (2000), aid effectiveness is affected by the various policy distortions that can lower its return. The authors suggest that the outcome of aid depends on how it is used (invested) and what motivates this investment. Moreover, A. C. Burnside and Dollar (2004) showed that aid contributes to growth depending on institutional quality as well as good policy environment. The authors suggested that if aid is automatically directed to countries with good institutions, it will increase the probability of its effectiveness.

In addition, whether for aid management or for coping with climate change induced by rising CO<sub>2</sub> emissions, good governance is important to avoid mismanagement, making it more difficult to achieve the SDGs in developing countries. Government effectiveness, relating to countries' economic and social growth Garcia-Sanchez et al. (2013), reflects the main objective of official development assistance. Moreover, as suggested by Bayasgalan (2015), the effective performance of an organization depends on the capacity of its employees to achieve goals and objectives. Fukuyama (2019) showed that the Korean government played a key role in the development process of Korea through its intervention in the allocation of credit and the acceleration of industrial development. However, corruption in developing countries is a serious obstacle to development when it comes to dealing with ODA. Mauro (1995) showed that if the integrity of the bureaucracy is improved it will lead to an increase in investment rate and thus, to economic growth. Moreover, A. C. Burnside and Dollar (2004) concluded that there is evidence that aid contributes to economic growth when associated with good institutions. However, Hansen and Tarp (2001) found that the impact of aid on economic growth was not conditional on good policy. Asongu and Odhiambo (2019b) showed that political governance had a positive effect on inclusive human development in sub-Saharan African countries.

Thus, as shown by the environmental Kuznet curve, an increase of carbon emissions doesn't always reflect a bad thing for developing countries because in many cases it materializes an increase in production. Add to this the fact that good governance plays a central role, whether for the implementation of policies enabling green economic growth but also for the effectiveness of ODA. Given the mitigated links existing between the main indicator of human development (HDI), carbon emissions, ODA (Official Development Assistance), and governance in developing countries, the main objective of the paper is the assessment of their interactions. This is done to optimize the achievement of the SDGs because these four variables are linked to most of these goals. SDGs being inseparable, the second objective is to see the impact of the combination of these variables on human development. This paper analyzes the effects of the combination of these variables, through interactive variables (carbon emissions and governance; carbon emissions and ODA; governance and ODA), on well-being. HDI has three dimensions: education, income and well-being. For better precision, the third objective of the paper is to assess the impact of carbon emissions, governance, and ODA on the indicators of those dimensions. This will enable policymakers in these countries to take an optimal approach to sustainable development. This paper will also help donors (ODA donors) to better direct their support.

The originality of this paper lies in the use of four main variables that are related to most of the SDGs to assess their interactions to optimize the realization of human development in developing countries. Moreover, the 2030 sustainable development agenda is a process that extends over a long period. This study goes further by considering the interactions between these different variables in the short and long term. Moreover, this paper's originality lies also in: first, the study fills the gap in the literature by incorporating CO<sub>2</sub> emissions, official development assistance (ODA), and governance as primary explanatory variables for human development in a single multivariate framework and using a large dataset of 56 developing countries. We divided the dataset into two groups, 29 low-income countries and 27 middle-income countries. Second, we used the novel cross-sectionally augmented ARDL to account for possible cross-section dependence, and possible endogeneity and to get consistent estimations in the short and long run. In addition, we used interactive variables (carbon emission and governance; carbon emission and ODA; governance and ODA), and AMG (Augmented Mean Group) for robustness check. Furthermore, we tested the impact of regressors on the main indicators of HDI. The paper allows us to have a particular vision of human development by considering the environmental aspect, governance, and assistance for development. In the current context of globalization, the interactions between these different variables are decisive, particularly for developing countries, because they can allow these countries to take off but also slow down their progress if they are poorly coordinated.

The rest of the paper is organized as follows: [Section 2](#) presents the theoretical and empirical literature on the nexus between human development, CO<sub>2</sub> emissions, governance, and ODA; [Section 3](#) discusses the methodological framework; [Section 4](#) presents the estimation results, while [Section 5](#) concludes and summarizes the policy implications of the study.

## 2. Literature review

In recent years, with the advent of the SDGs (sustainable development goals) and the various disasters that have shaken the planet, the fight against climate change through the reduction of carbon emissions has become a priority for all nations. However, one of the most widely used development indicators is the Human Development Index (HDI), because of its direct relationship with most SDGs. One of the most used ways to assess the nexus between economic growth and environmental pollution is through the Environmental Kuznet Curve (EKC). The latter is based on five perspectives: economic structure change, income inequality, international trade, technological progress, and policy guidance. Economic change, as suggested by Shafik and Bandyopadhyay (1992), refers to the transition from an intensive and heavy industry to a technology-intensive, information technologies and service industry. This reflects the fact that at an early stage of development, pollution rises with economic growth but restructuring of industry with improvements in technology will help to reduce pollution. Second, as suggested by Magnani (2000), an increase in income level will raise people's awareness of environmental protection and increase their spending on environmental protection research. Third, as suggested by Lopez (2017), countries use their comparative advantages in international trade. Thus, developed countries are characterized by high-technology industries for economic growth while developing countries are characterized by labor-intensive industries with high pollution. Fourth, as suggested by Selden and Song (1994), technological progress plays a key role in the EKC hypothesis. For the authors, investing in clean technologies leads to the greening of the production process and thus, helps to combat environmental pollution problems at the source. Fifth, as suggested by Wara (2007), when a country reaches a high level of development, the government and the people start to pay more attention to environmental pollution problems and take measures through policies.

Thus, the assessment of the HDI-carbon emission relationship is therefore becoming a priority. In the literature, as suggested by Goldstein (2015), this relationship is mixed. Pervaiz et al. (2021) used data from 2000Q1 to 2014Q4 for BRICS countries to analyze the link between the human development index, renewable energy, and other factors. They found that HDI and renewable energy negatively affect CO<sub>2</sub> emissions. Steinberger et al. (2012) studied how the relationship between human development and carbon emissions changes when we adjust national emission rates for trade. They found that high life expectancies are compatible with low carbon emissions, but high income is not. They suggested that the relationship between carbon emission and human development depends on the income level of the



nation. Aqib and Zaman (2023) studied how improving human capital can make a country more prosperous through environmental sustainability. The results suggested that economic growth causes carbon emissions on the one hand while increasing life expectancy on the other hand. These findings reflect the complexity of the relationship between human development and carbon emissions.

Payab et al. (2023) explored human capital's impact on carbon emissions in nine leading carbon emitter nations. They found that human capital moderates carbon emissions when interacting with industrial value-added and per capita income. Wang et al. (2023) investigated the nexus between consumption-based carbon emissions, sustainable energy, natural resources, and human capital using CS ARDL. The findings suggested that cleaner energy, natural resources, and human capital preserve environmental quality. Sheraz et al. (2021) studied the link between human capital, carbon emissions, and other factors. They found that financial development and human capital decreased carbon emissions, while GDP and energy consumption increased carbon emissions. Given the fact that human capital and GDP are considered indicators for human development indicators, the findings suggest that the impact of carbon emission on the human development index depends on the indicator of development used. Dumor et al. (2022) investigated the relationship between carbon emissions and the human development index. They employed the novel dynamic autoregressive-distributed lag (DARDL) with East Africa Community (EAC) countries and data from 1980 and 2020. They found that human development had a strong positive correlation with carbon emissions in the short and long term.

In addition, reducing carbon emissions, like achieving the other SDGs, requires substantial funding, which in the case of developing countries is channeled through ODA. Determining the ODA-human development relationship is therefore a priority for better aid orientation. Official development assistance allocation is based on the 'donor's interest' (DI) and 'recipient's needs' (RN) according to international political theories Maizels and Nissanke (1984). States are rational actors in international politics and relations. According to DI theory and the theory of realism, states are always trying to maximize their economic and military interests. Thus, the official development allocation's main target is to expand the economic, military, and diplomatic interests of donors. However, the RN theory reflects the liberalism of international politics. According to this theory (RN theory) aid is allocated to reduce the development gap between countries to facilitate exchanges. Moreover, for this theory, democracy is a key factor for peace and prosperity. Thus, donors allocate more aid for democratic reforms and human rights advancements. In addition, Bandyopadhyay and Wall (2006) showed that more aid has been directed to low-income countries with high rates of infant mortality.

As for the impact of carbon emissions on HDI, the impact of development assistance is also mixed. This impact can be non-linear, can depend on the type of aid considered, be dynamic concerning the short and long term, or depend on the level of development of the country under consideration. Sardar (2022) analyzed the link between aid for trade and human development. They found that aid for trade has a positive and significant influence on human development, both in the short and long run. Ozigbu (2018) assessed the effectiveness of aid in improving human development. The results showed that technical cooperation grant exerts a significant positive impact on human development in Nigeria in both the short and long run while net ODA received harms human development indicators in the short run. Githaiga and Kilong'i (2023) investigated the moderating effect of governance on the relationship between foreign capital flows and human capital development. The results suggested that the foreign direct investment and remittances effect on human capital is moderated by institutional quality while ODA effect on human capital is not affected by institutional quality.

Asongu et al. (2019) investigated the incidence of aid on inclusive human development in sub-Saharan African countries. They found that when foreign aid is between 60 and 150 (% of GDP) it has a positive effect on inclusive human development. The authors suggested that countries with a low level of development need substantial funding to reach inclusive development compared to their counterparts. Yiheyis and Woldemariam (2020) assessed the relative contributions of aid to human development outcomes in 35 African countries over three decades. The results suggested that ODA exerted modest favorable effects on human development. However, the effect of ODA on HDI seemed to be affected by the level of real GDP per capita, the quality of institutions, and the size and degree of instability of ODA flows. Narteh-Yoe et al. (2023) examined the impact of foreign direct investment (FDI), aid, and domestic investment on economic growth in small states. The findings suggested that aid harms economic

growth in poor countries while domestic investment and FDI positively impact economic growth. The results also showed that the interactive terms of aid with FDI, aid with trade openness, and aid with domestic investment and FDI had a positive effect on economic growth.

As suggested by Fukuyama (2019) building a strong state is a prerequisite for economic growth. for Isham et al. (1997) open governance, and public accountability lead to greater government effectiveness and, more efficient resource allocation. The authors suggested that this type of institution is more likely to adopt pro-poor public policies. Moreover, Rodrik (2000) showed that the ability of countries to respond to financial crises depended on the quality of institutions. Good institutions provide mechanisms to respond to shocks more effectively. In addition, in terms of official development assistance effectiveness, government officials play a key role because they are the major actors in spending and managing aid. As Yiheyis and Woldemariam (2020) suggest, the effectiveness of foreign aid depends on the quality of institutions. This is also the case for climate change mitigation and the achievement of the other SDGs for sustainable human development.

Gaur and Kant (2020) employed data from nineteen very high human development countries from 2000 to 2016. They found that governance had a facilitating role in the development process. Achim et al. (2023) investigated the effect of corporate governance on sustainable development. The finding showed that corporate governance had a positive impact on sustainable development measured by the human development index, human capital index, and environmental performance index. Asongu and Odhiambo (2019) investigated the effect of government quality on inclusive human development. The results showed that governance moderated the negative effect of CO<sub>2</sub> emissions on inclusive human development. Moreover, the interactive term of governance and CO<sub>2</sub> emission had a positive effect on inclusive HDI. Hashem (2019) analyzed the impact of governance on human development in MENA countries. They used data of 20 countries during the period (1996–2017). They found that there is a significant relationship between governance and human development.

Thus, as the literature shows, results on the relationship between HDI, carbon emission, governance, and ODA are mixed. The literature suggested that the nexus between those variables can be positive or negative based on the income level of the country. To avoid this matter, we divided the sample into two parts, low-income countries, and middle-income countries. Moreover, the literature showed that improving human development requires the combination of numerous factors. Thus, we used interactive terms of the main explanatory variables to assess their impact on human development and to check the robustness of the results. To our knowledge, no study analyzes the direct link between carbon emissions, official development assistance, governance, and different dimension of human development. For that matter, we divided human development based on its dimensions to assess the impact of carbon emissions, ODA, and governance on them. In addition, the mixed results found in the literature can be due to the approach used for the analysis. To remedy this without forgetting to consider cross-section dependence, slope heterogeneity, endogeneity, and autocorrelation we opted for the novel cross-sectionally augmented autoregressive distributed lag (CS ARDL) method for this study. As suggested by Chudik (2016) panel CS-ARDL estimates are robust to endogeneity problems, residual serial correlation, breaks in error processes, and dynamic misspecifications. In addition, AMG (Augmented Mean Group) is used for robustness check. These models provide robust results considering cross-section dependence, and slope heterogeneity. More information on the CS ARDL is provided in the methodology section.

### 3. Methodology

#### 3.1. Data and variable description

The data used for this study are from World Bank Development Indicators (WDI),<sup>1</sup> World Governance Indicators (WGI),<sup>2</sup> UNDP,<sup>3</sup> and OECD<sup>4</sup> from 2005 to 2019 from 56 developing countries reported in table (see Appendix A). The human development index is the dependent variable. The latter reflects human wellbeing through three dimensions: a healthy life, a good education, and better living standards. Carbon emissions are those stemming from the burning of fossil fuels and the manufacture of cement including carbon dioxide produced during the consumption of solid, liquid, and gas fuels and gas flaring. As suggested by Opoku et al. (2022), a rise in human development leads to better environmental



sustainability through reduction of carbon emissions and air pollution. The expected impact of carbon emissions on human development is negative. Official development assistance (ODA) is the total amount of assistance received by a country from official donors. As shown by S. Asongu and Nnanna (2019) foreign aid improves inclusive human development in the short run. The expected impact of ODA on human development is positive. Energy intensity reflects the amount of energy required to produce on unit of output. Ouedraogo (2013) found that there was a negative cointegration between the human development index and energy consumption in the long term. The expected impact of energy intensity on human development is negative. Governance effectiveness captures the perceptions of the quality of public services, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. For Pradhan (2011), good institutions and good governance can increase the level of economic growth and human development. The expected impact of governance on human development is positive.

### 3.2. Theoretical frameworks

Classic approaches for detecting long-run relationships between variables had one main limitation, all series had to be integrated at the same order. However, the auto-regressive distributed lag model (ARDL) developed by Pesaran et al. (2001) appeared as a solution to address this issue. The classic ARDL had some advantages in comparison to other cointegration methods. This approach allows us to get robust short and long-run coefficients without imposing any restriction on the order of integration of the variables. The ARDL model is not sensitive to sample size which makes it suitable even if the sample size is small. In addition, the ARDL approach provides unbiased information even when some of the variables in the regression are endogenous.

During the last decade, the level of globalization, whether economic, political, or even social has continued to increase, particularly with innovations in ICT (information and communication technologies). This interdependence makes the study of most phenomena on the country level complex because of cross-section dependence which can bias the results if it is not controlled. Moreover, despite this globalization, countries remain different in terms of development, even those with the same resources, because of certain factors specific to them. This particularity of countries coupled with their interdependence requires an estimation method that can overcome the biases that these two phenomena can cause. Country-specific distinctions and the complexity of the global economy creating interdependence between countries make the estimations of the results using conventional approaches difficult because it may lead to biases Everaert and De Groote (2016).

Thus, to account for possible cross-section dependency, slope heterogeneity with robust estimates for short and long-run relationships we opted for cross-sectionally augmented autoregressive distributed lag (CS ARDL) developed by Chudik (2016) and the AMG (Augmented Mean Group) method developed by Eberhardt and Teal (2010). The same approach has been used in several papers Kamalu et al. (2022); Uddin et al. (2023) to address issues related to cross-section dependency, slope heterogeneity, and omitted variable bias. For more precision, we divided the panel into two parts considering the level of income, i.e. 29 countries with low income and 27 countries with middle income. For more precision on the nexus between human development, carbon emission, official development assistance (ODA), and governance we used their interactive terms to assess their effects on wellbeing.

### 3.3. Econometric strategies

Based on the literature above the basic equation is as follows:

$$HDI_{it} = \beta_0 + \beta_1 co2emission_{i,t} + \beta_2 ODA_{net_{it}} + \beta_3 gov\_effect_{it} + \beta_4 en\_int_{it} + \varepsilon_{it} \quad (1)$$

Where *HDI* is the human development index, *co2emission* is the carbon emissions, *ODA<sub>net</sub>* is the net official development assistance received from official donors, *en\_int* is the energy intensity, *gov\_effect* is the governance effectiveness,  $\varepsilon_{it}$  is the error term. To overcome cross-section dependency and slope heterogeneity, we opted for cross-section autoregressive distributed lag (CS ARDL) developed by Chudik

(2016). This approach of CS ARDL is superior to other methods because it adds additional lags to the ARDL specification to account for heterogeneity and cross-sectional dependencies. In addition, the CS ARDL displays robust results for the short and long run even when the variables are integrated at different orders.

Before estimating CS ARDL model, we executed several pre-estimation tests to ensure consistent results for policy implications. First, we tested for cross-sectional dependence (CD) and slope heterogeneity. It's paramount in panel data to control for these two issues to ensure consistent results and choose appropriate unit root and cointegration tests. Pesaran (2021) test for the cross-section dependence equation is as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^N \rho_{ij} \right) \sim N(0, 1)_{i,j} \quad (2)$$

$$R = \sqrt{\frac{2T}{N(N-1)}} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_j \right) \left[ (M-k) \frac{\hat{\rho}_{ij}^2 - (T-k)\hat{\rho}_{ij}^2}{Var(T-k)\hat{\rho}_{ij}^2} \right] \quad (3)$$

Where  $\hat{\rho}_{ij}^2$  denotes the cross-country correlation of residual for  $i$  and  $j$  obtained from the panel's individual ordinary least square (OLS) regression. The stability of the panel depends on the existence of slope homogeneity or heterogeneity in the panel. To validate that the model has a heterogeneous slope, we used Pesaran and Yamagata (2008) test for slope homogeneity. The two-statistics delta  $\hat{\Delta}_{HS}$  and adjusted delta  $\hat{\Delta}_{adjHS}$  are displayed in Equation (4) and (5):

$$\hat{\Delta}_{HS} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}} \left( \frac{1}{N} \hat{S} - k \right) \quad (4)$$

$$\hat{\Delta}_{adjHS} = (N)^{\frac{1}{2}} \left( \frac{2k(T-k-1)}{T+1} \right)^{-\frac{1}{2}} \left( \frac{1}{N} \hat{S} - k \right) \quad (5)$$

Second, we tested unit root in the data using second-generation panel unit root tests such as CIPS test developed by Pesaran (2007) because first-generation unit root tests assume model slope homogeneity and cross-section independence, which may lead to inaccurate results. This test considers those two issues by augmenting each cross-sectional entity with cross-sectional averages of lagged and first difference values of analyzed variables. The test statistic under the null hypothesis of homogenous non-stationarity is stated in Equations (6) and (7):

$$\Delta Z_{i,t} = \omega_i + \omega_i Z_{i,t-1} + \omega_i \bar{Y}_{t-1} + \sum_{i=0}^p \omega_{i1} \Delta \bar{Z}_{t-1} + \sum_{i=1}^p \omega_{i1} \Delta Z_{i,t-1} + \varepsilon_{it} \quad (6)$$

$$CIPS = \frac{1}{N} \sum_{i=1}^N t_i(N, T) \quad (7)$$

Where  $\bar{Y}_{t-1}$  and  $\Delta \bar{Z}_{t-1}$  are the cross-sectional average estimates of the lagged variable and the first difference for each cross-section, respectively. Third, given the limited number of observations per country, we used Westerlund (2005) test for cointegration analysis since it can be applied to slope heterogeneous models and also considers cross-section dependency. The VR (variance ratio) test statistics are obtained by testing for a unit root in the predicted residuals. We tested the null hypothesis of no cointegration against the alternative hypothesis that all the panels are cointegrated following Equation (8):

$$VR = \sum_{i=1}^N \sum_{t=1}^T \hat{E}_{it}^2 \left( \sum_{i=1}^N \hat{R}_i \right)^{-1} \quad (8)$$

The asymptotic distribution of the test statistics, after appropriate standardization, converges to  $N(0,1)$ . Finally, we performed CS ARDL given its numerous advantages compared to other econometrics models such as managing endogeneity due to reverse causal relationships between model variables and addressing omitted variables biases. The CS ARDL equation is as follows:

$$HDI_{it} = \sum_{j=1}^p \phi_{ij} HDI_{i,t-j} + \sum_{j=0}^q \vartheta_{ij} X_{i,t-j} + \sum_{j=0}^r \alpha_{ij} \bar{Z}_{t-1} + \mu_i + \varepsilon_{it} \quad (9)$$

Where  $\bar{Z}_{t-1} = (\overline{HDI}_{i,t-1}, \bar{X}_{i,t-1})$  are the average of the regressand and regressor.  $P, q$  indicates the lag of the variables and  $r$  indicates the number of lags of the cross-sectional averages to be included.  $X_{i,t}$  is a set of explanatory variables (the carbon emissions, the net official development assistance received from official donors, governance effectiveness, energy intensity) and  $\varepsilon_{it}$  is the error term.  $\bar{Z}$  represents cross-section averages and avoids cross-section dependence Azam et al. (2022). The long-run coefficients are estimated as follows:

$$\hat{\gamma}_{CSARDL,j} = \frac{\sum_{j=0}^q \hat{\vartheta}_{ij}}{1 - \sum_{j=1}^p \hat{\phi}_{ij}} \quad (10)$$

The mean group is as follows:

$$\hat{\gamma}_{MG} = \sum_{j=1}^N \hat{\gamma}_{ij} \quad (11)$$

The short-run with error correction form is as follows:

$$\Delta HDI_{it} = \delta_i [HDI_{i,t-j}, \rho_{ij} X_{i,t-j}] - \sum_{j=1}^{p-1} \phi_{ij} \Delta_j HDI_{i,t-j} + \sum_{j=0}^q \vartheta_{ij} \Delta X_{i,t-j} + \sum_{j=0}^r \alpha_{ij} \bar{Z}_{t-1} + \mu_i + \varepsilon_{it} \quad (12)$$

Where  $\Delta_j = t - (t - 1)$

Cross-section dependency and slope heterogeneity are important issues for dynamic panels. CCEMG (Common Correlated Effect Mean Group) which is based on the same specification as the CS ARDL, is one of the methods used to address those issues, as well as the AMG (Augmented Mean Group) which is employed for robustness check in this paper. The AMG method, developed by Eberhardt and Teal (2010), has some advantages such as providing robust results in the presence of cross-section dependency, heterogeneity, missing data, serial correlation, or other sources of non-stationarity. Moreover, this estimator uses explicit estimates for unobserved common factors to exhibit a common dynamic process as a meaningful construct while the CS ARDL estimator uses implicit estimates for unobserved common factors with cross-sectional averages of regressors. In addition, the variables used for this paper are displayed in Table 1.

#### 4. Presentation of the results

Table 2 shows the summary statistics of the selected variables. The number of observations is the same for all variables in the dataset which is a necessity to run the CS ARDL and the related tests. The mean of HDI, carbon emissions, governance, and ODA are 0.597, 0.204, -.568, and 1138.253 while their maximum is 0.825, 1.256, 0.644, and 22057.09, respectively. The standard deviation of governance, gross income per capita, and energy intensity are 0.486, 4777.371, and 3.2, respectively which indicate a high level of variability for those variables. In addition, the standard deviation of HDI, carbon emissions, and life expectancy are 0.113, 0.168, and 6.104 respectively which indicate a low level of variability for those variables.

The current study uses 56 developing countries which increases the possibility of cross-sectional dependency among the selected countries because of the interconnection through trade and financial integration. CD (cross-section dependency) denotes the impact of a shock from one country to another. In this study, we employed a CD test to assess the possibility of CD. The results are displayed in Table 3. We used two tests to detect weak cross-section dependency, the cross-section test developed by Pesaran (2021), and for robustness check, we used the cross-section test with power enhancement developed by Fan et al. (2015). The findings suggest that the null hypothesis of no cross-section dependency is rejected for all variables. Furthermore, the stability of the panel depends on the existence of slope homogeneity or heterogeneity in the panel. Thus, neglecting possible heterogeneity in the

**Table 1.** Description of variables.

Name	Description
CO2emission	CO <sub>2</sub> emissions (kg per 2017 PPP \$ of GDP) source WDI
Ene_int	Energy intensity level of primary energy (MJ/\$2017 PPP GDP) Energy intensity is an indication of how much energy is used to produce one unit of economic output. source WDI
Gov_effect	Government Effectiveness: source WGI
ODAnet	Total ODA (official development assistance) received from official donors. source: OECD
HDI	The human development index summarizes three key aspects: a healthy life, good education, and better living standards. Source UNDP
life_expect	Life expectancy. source UNDP
expect_school	Expected year of schooling. source UNDP
gross_incom	Gross national income per capita. Source UNDP
Gov_co2	The interactive term between governance effectiveness and carbon emission. source author
Gov_oda	The interactive term between governance effectiveness and ODA. source author
Oda_co2	The interactive term between ODA and carbon emission source author. Source author

**Table 2.** Descriptive statistics.

Variable	Obs	Mean	Std. dev	Min	Max
HDI	840	0.597	0.113	0.332	0.825
CO2emission	840	0.204	0.168	0.029	1.256
ODAnet	840	1138.253	1693.207	27.05	22057.09
Gov_effect	840	-0.568	0.486	-2.078	0.644
Ene_int	840	5.782	3.213	1.93	21.44
life_expect	840	70.672	6.104	48.252	80.28
expect_school	840	12.058	2.031	5.742	15.651
gross_incom	840	8607.915	4777.371	1902.972	23,136.89

slope coefficients can lead to bias. For this study, we used the Pesaran and Yamagata (2008) method to test for slope homogeneity. The results obtained in Table 4 showed that there was slope heterogeneity in the variables with delta and delta adjusted significant at 1%, suggesting disparity in developing countries.

Given the presence of cross-section dependency (CD) and slope heterogeneity, the first-generation panel unit root may produce biased results. To get over this bias, we used the CPIS which is a second-generation unit root test, and CADF test for robustness check. The results in Table 5 show that all variables are stationary after the first difference. Furthermore, these findings show that some variables are integrated at order one  $I(1)$  and others are integrated at level  $I(0)$ . The findings are confirmed by the results of the test developed by Maddala and Wu (1999) which takes into account heterogeneity. In addition, we performed a cointegration analysis using Westerlund (2005) cointegration test. The results displayed in Table 6 showed that the null hypothesis of no cointegration between the variables is rejected. These findings suggest a long-run relationship between human development and its main parts (life expectancy, expected years of schooling, gross national income) with the explanatory variables and thus reinforce the choice of CS ARDL for the estimation. For the robustness check, we used the cointegration test developed by Pedroni (2004) which has two types of classes, the within dimension and the between dimension. The robustness check confirmed the existence of cointegration between variables. The table also displays the results of the BDS nonlinearity test developed by Broock et al. (1996). The results show that we can't reject the null hypothesis suggesting that the series are linearly distributed, and thus, CS ARDL and AMG can be used to assess the nexus between human development, carbon emissions, governance, and official development assistance. Moreover, the table displays the results of a specification test developed by Hausman (1978). The finding of the Hausman test recommends the use of a random effect model. However, in the presence of cross-section dependency, a model using common correlated effect such as CS ARDL and AMG can be used to correct the random effect.

The CS ARDL, and AMG are employed to assess the nexus between human development and the explanatory variables in the short and long run reported in Table 7. ODA has a negative and significant effect on HDI in the short run for all countries. This effect of ODA is negative and significant in low-income countries but not significant in middle-income countries. This result reflects the inefficiency of development aid, especially in developing countries, where aid is often not accompanied by good governance, rigorous monitoring, and above all, proper allocation to growth-generating sectors. The same negative result was found by Groß and Nowak-Lehmann Danzinger (2022). With 27 developing

**Table 3.** Cross-section dependence test.

	ALL COUNTRIES		MIDDLE-INCOME COUNTRIES		LOW-INCOME COUNTRIES	
	CD	CDw+	CD	CDw+	CD	CDw+
InHDI	132.180 (0.000)	5576.100 (0.000)	64.570 (0.000)	1236.410 (0.000)	66.150 (0.000)	1517.830 (0.000)
Inc02emission	−1.020 (0.307)	2635.360 (0.000)	4.340 (0.000)	659.350 (0.000)	3.890 (0.000)	653.060 (0.000)
InODAnet	22.020 (0.000)	1956.710 (0.000)	4.720 (0.000)	458.180 (0.000)	19.420 (0.000)	587.990 (0.000)
InGov_effect	4.640 (0.000)	1970.830 (0.000)	5.410 (0.000)	532.370 (0.000)	−0.500 (0.616)	450.740 (0.000)
InEne_int	47.680 (0.000)	3155.040 (0.000)	28.510 (0.000)	767.910 (0.000)	18.130 (0.000)	811.680 (0.000)
Inlife_expect	150.000 (0.000)	5883.780 (0.000)	71.410 (0.000)	1343.480 (0.000)	77.230 (0.000)	1554.240 (0.000)
Inexpect_school	79.920 (0.000)	4556.510 (0.000)	32.920 (0.000)	1046.940 (0.000)	46.580 (0.000)	1211.780 (0.000)
Ingross_incom	108.730 (0.000)	4655.340 (0.000)	57.810 (0.000)	1095.250 (0.000)	49.990 (0.000)	1206.240 (0.000)

Note.  $p$  value between (); CD: weak cross-section test Pesaran (2021) CDw+: CD with power enhancement Fan et al. (2015).

**Table 4.** Slope homogeneity test.

All countries	Statistic	$p$ Value
$\hat{\Delta}_{HS}$	19.365	0.000
$\hat{\Delta}_{adjustmentHS}$	25.000	0.000
Middle-income countries	Statistic	$p$ Value
$\hat{\Delta}_{HS}$	14.338	0.000
$\hat{\Delta}_{adjustmentHS}$	18.510	0.000
Low-income countries	Statistic	$p$ Value
$\hat{\Delta}_{HS}$	13.037	0.000
$\hat{\Delta}_{adjustmentHS}$	16.830	0.000

**Table 5.** CIPS, CADF, and MADALLA and WU unit root test.

ALL COUNTRIES Variable	CIPS		CADF		MADDALA AND WU		Order of integration
	level	First difference	level	First difference	Level	First difference	
InHDI	(−2.295)	(−3.794)***	(−1.975)	(−2.513)***	(53.588)	(483.92)***	I(1)
Inc02emission	(−2.378)	(−3.508)***	(−2.051)*		(136.787)	(510.40)***	I(0)
InODAnet	(−2.783)***		(−1.730)	(−2.696)***	(215.314)*		I(0)
InGov_effect	(−2.748)**		(−2.047)*		(212.546)	(709.67)***	I(0)
InEne_int	(−2.432)	(−3.404)***	(−2.356)***		(175.614)**		I(0)
InLife_expect	(−0.771)	(−2.707)**	(−3.444)***		(666.686)	(224.38)***	I(1)
InSchool_expect	(−2.546)*		(−1.624)	(−2.398)***	(101.665)	(592.57)***	I(0)
InGross_incom	(−1.815)	(−3.157)***	(−1.495)	(−2.195)**	(104.752)	(505.07)***	I(1)
MIDDLE-INCOME							
InHDI	(−2.459)	(−3.810)***	(−1.916)	(−2.712)***	(33.778)	(217.01)***	I(1)
Inc02emission	(−2.116)	(−3.249)***	(−2.014)	(−2.403)***	(67.814)	(296.80)***	I(1)
InODAnet	(−2.205)	(−4.063)***	(−1.530)	(−2.504)***	(102.982)	(485.13)***	I(1)
InGov_effect	(−2.144)	(−4.014)***	(−2.194)**		(67.744)*		I(0)
InEne_int	(−2.532)	(−3.608)***	(−2.408)***		(88.560)	(337.12)***	I(0)
InLife_expect	(−1.178)	(−3.205)***	(−1.983)	(−2.519)***	(450.255)*		I(0)
InSchool_expect	(−2.294)	(−3.654)***	(−1.535)	(−2.220)**	(50.640)	(260.14)***	I(1)
InGross_incom	(−1.789)	(−2.778)**	(−1.685)	(−2.192)**	(60.149)	(229.86)***	I(1)
LOW-INCOME							
InHDI	(−2.186)	(−3.350)***	(−2.027)	(−2.319)**	(19.810)	(252.91)***	I(1)
Inc02emission	(−2.287)	(−3.506)***	(−1.675)	(−2.739)***	(68.973)	(275.94)***	I(1)
InODAnet	(−3.172)***		(−2.005)	(−3.193)***	(112.332)	(396.50)***	I(0)
InGov_effect	(−2.545)	(−4.079)***	(−1.402)	(−2.221)**	(144.80)*		I(0)
InEne_int	(−2.328)	(−3.461)***	(−2.119)*		(87.05)*		I(0)
InLife_expect	(−0.754)	(−2.622)*	(−4.065)***		(216.431)	(164.78)***	I(0)
InSchool_expect	(−2.579)	(−3.622)***	(−1.676)	(−2.262)**	(51.025)	(388.37)***	I(1)
InGross_incom	(−1.394)	(−2.579)***	(−1.900)	(−3.394)***	(44.604)	(244.16)***	I(1)

CIPS, CADF and MADDALA AND WU statistics between(): (\*), (\*\*) and (\*\*\*) significant at 10%, 5% and 1%.

**Table 6.** Cointegration tests, nonlinearity test and specification test.

All countries	Dependent variable	Westerlund test	Pedroni test		
		Variance ratio statistic	Modified Phillips–Perron	Phillips–Perron	Augmented Dickey–Fuller
	lnHDI	(6.537)***	(7.240)***	(−5.174)***	(−4.963)***
	lnlife_expect	(7.060)***	(6.704)***	(−5.154)***	(−6.356)***
	lnexpect_school	(5.246)***	(7.602)***	(−3.787)***	(−3.901)***
	lngross_incom	(4.576)***	(7.165)***	(−3.832)***	(−3.452)***
Middle-income	Dependent variable	Statistic	Modified Phillips–Perron	Phillips–Perron	Augmented Dickey–Fuller
	lnHDI	(3.164)***	(4.774)***	(−3.740)***	(−3.834)***
	lnlife_expect	(3.602)***	(4.207)***	(−5.208)***	(−7.257)***
	lnexpect_school	(1.982)**	(5.309)***	(−2.796)***	(−3.51)***
	lngross_incom	(1.847)**	(4.863)***	(−2.906)***	(−3.362)***
Low-income	Dependent variable	Statistic	Modified Phillips–Perron	Phillips–Perron	Augmented Dickey–Fuller
	lnHDI	(6.031)***	(5.069)***	(−2.643)***	(−3.196)***
	lnlife_expect	(6.334)***	(5.302)***	(−1.880)**	(−1.829)**
	lnexpect_school	(5.376)***	(5.207)***	(−2.287)**	(−1.956)**
	lngross_incom	(4.576)***	(5.084)***	(−2.708)***	(−1.553)**
Nonlinearity test (BDS)					
Dimension	lnHDI	lnCo2emission	lnEne_int	lnGov_effect	lnODAnet
2	(1.282)	(1.026)	(−1.170)	(−0.015)	(1.326)
3	(2.477)	(1.175)	(−1.340)	(0.552)	(0.642)
4	(2.821)	(0.926)	(−1.674)	(0.128)	(0.207)
HAUSMAN TEST					
	Test statistics (1.510)				

Note. Test statistic between(): (\*, \*\* and \*\*\*) significant at 10%, 5% and 1%.

countries, the authors found that foreign aid harms TFP (total factor production), the latter reflecting sustained growth and hence development. Apart from the management of aid in developing countries, the sector in which this assistance is directed to plays a paramount role in aid effectiveness. Afoakwa (2016) who analyzed the effectiveness of aid in 46 Sub-Saharan countries found a positive impact of aid on human development which becomes negative in the long run. For the author, this mixed effect of official assistance is because aid, since the end of Cold War, has been mostly allocated to the social sector. Thus, the benefits from this type of aid are minimal and temporary. Furthermore, Lee et al. (2019) found that aid directed to public service and health care had a positive impact on human development except for aid in the water and sanitation sector which was not significant while assessing aid effectiveness in 15 Asian countries. The authors suggested an assessment of each country's optimal combination of aid sub-programs for better allocation of ODA (Official Development Assistance).

Government effectiveness has a positive and significant effect on HDI in the short and long run for all countries. This effect remains positive and significant for low-income countries. This highlights the important role played by institutions in the development process as they enable the mobilization of investment through the improvement of the business climate, and optimization of resources through proper allocation all of which allow an increase in productivity and grounds for economic development. This result is in line with Uddin et al. (2023) who also found that apart from the positive effect of institutional quality on the human development index a rise of 1% in corruption leads to a decrease of 0.3% in HDI. Given that corruption is one of the main challenges facing developing countries as it discourages investment and creates income inequalities, this result emphasizes the need for effective institutions to achieve human development. Moreover, Sarkodie and Adams (2020) found that the combination of income inequalities and the political environment has a negative impact on human development when examining the nexus between governance, access to energy, and human development in Sub-Saharan Africa. In addition, the authors found that the combination of access to energy and political environment had a positive impact on human development. These findings reflect the necessity to mix governance with the right factor, based on the needs of the country, to optimize the positive impact of institutional quality.

Carbon emission has a positive and significant effect on HDI in the short and long run for all countries. The same result was found for middle-income countries. The positive relationship between HDI and carbon emission can be explained through the desire of increasing economic growth which leads to an increase in energy use. As shown by Sikder et al. (2022) for developing countries and Mehmood et al. (2022) for G-11 economies, an increase in GDP leads to an increase in CO<sub>2</sub> emissions. This result



**Table 7.** Estimations of the regressors' impact on human development index.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI
<b>SHORT RUN</b>						
L.lnHDI	0.497*** (0.000)		0.445*** (0.000)		0.505*** (0.000)	
D.Inc02emission	0.070** (0.011)	0.078** (0.030)	0.089** (0.019)	0.090** (0.016)	0.053 (0.205)	0.036 (0.507)
D.lnODAnet	-0.001** (0.036)	-0.001 (0.232)	0.000 (0.972)	0.000 (0.532)	-0.002** (0.019)	-0.002* (0.067)
D.lngov_effect	0.003* (0.075)	0.000 (0.936)	0.000 (0.212)	-0.000 (0.976)	0.003 (0.114)	0.004** (0.040)
D.lnene_int	-0.005*** (0.000)	-0.005*** (0.001)	-0.004*** (0.000)	-0.004*** (0.001)	-0.006** (0.017)	-0.006** (0.045)
<b>LONG RUN</b>						
lr_lnODAnet	0.005 (0.426)	-0.001 (0.500)	0.021 (0.137)	0.001 (0.591)	-0.006 (0.254)	-0.003 (0.124)
lr_lnc02emission	0.285 (0.622)	0.134** (0.012)	-2.463 (0.399)	0.226*** (0.000)	0.454 (0.132)	0.009 (0.895)
lr_lnene_int	-0.036*** (0.005)	-0.009*** (0.006)	0.002 (0.920)	-0.014** (0.017)	-0.029* (0.064)	-0.004 (0.234)
lr_lngov_effect	0.060 (0.125)	0.007** (0.041)	-0.096 (0.363)	0.004 (0.349)	-0.025 (0.424)	0.011** (0.012)
ECT	-0.503*** (0.000)	-0.677*** (0.000)	-0.555*** (0.000)	-0.77*** (0.000)	-0.495*** (0.000)	-0.718*** (0.000)
Observations	840	840	405	405	435	435
R-squared	0.278		0.317		0.250	
Number of countries	56	56	27	27	29	29

Note. pval in parentheses\*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

on the nexus between HDI and carbon emission is in line with Tatli (2022) who found the same link for OECD countries. However, this positive link between carbon emissions and growth is not in line with the sustainable development goals suggesting sustained economic growth while protecting the environment. One of the ways to moderate carbon emissions is through good governance. Akhbari and Nejati (2019) showed that a decrease in corruption level led to a decrease in carbon emissions for developing countries while for developed countries a decrease in the level of corruption has no significant effect. In addition, Q. Li and Chen (2021) showed that it's paramount to assess the relationship between carbon emissions and human development. For the authors, this relationship must be assessed through human needs by establishing a series of minimum goods and services and estimating carbon emissions related to those goods and services. This will allow us to provide better guidance to switch to low carbon emissions lifestyle.

Energy intensity, reflecting how much energy is used to produce one unit of economic output, has a negative and significant effect in the short run on HDI for all countries. The same effect is found in low- and middle-income countries in the short and long run. This result suggests that a decrease in the amount of energy used to produce one unit of economic output, thus reflecting optimal management of energy resources, can lead to an increase in human development. In addition, Musakwa and Odhiambo (2022) who investigated the impact of energy consumption on human development in South Africa, found that energy consumption had a positive impact on HDI in the short run when renewable energy was used as a proxy and a negative impact when oil products, natural gas, and total energy were used as proxies for energy. However, Ouedraogo (2013) showed that energy consumption has a negative impact on human development in developing countries while electricity consumption has a positive impact. All this reflects the need for better management of energy sources. The findings also emphasize the fact that every type of energy source has a different impact on human development depending on the country considered. Moreover, as suggested by Yumashev et al. (2020) renewable energy sources contribute to higher economic development while preserving the environment.

The ECT coefficients are -0.503, -0.555, and -0.495 and are statistically significant for the global model, low- and middle-income countries respectively. These results demonstrate that the annual adjustment to long-run equilibrium is around 50%, 55.5%, and 49.5% for all, low- and middle-income countries respectively. Furthermore, for a robustness check of the results, we used interactive terms to assess the effect

of the combination of carbon emissions, ODA, and governance effectiveness on HDI. As suggested by the literature governance can moderate the effects of carbon emissions on HDI. Table 8 reports the results of CS ARDL model using the interactive term of governance effectiveness and carbon emissions.

We note that the estimates remained globally unchanged in terms of the significance of the coefficients and their sign, compared to the estimates without interactive terms. The results show that ODA kept a negative and significant impact on HDI in the short run for all countries. This impact is negative and significant in the short run for low-income and not significant for middle-income countries. Energy intensity kept a negative and significant impact on HDI in the short run for the global model. However, the impact of the interactive term of governance and carbon emissions is positive and significant in the short- and long-run for low-income countries. This impact is positive and significant for all countries in the long run. This positive impact reflects the fact that the establishment of strong institutions helps to counter the negative effects of carbon emissions on human development. Omri et al. (2020), after showing the positive link between economic growth and carbon emissions, the authors showed that good governance can moderate the negative impact of carbon emissions on human development but also the positive impact of economic growth on carbon emissions. The same positive impact of the interactive term of governance and carbon emissions on human development was found by Asongu and Odhiambo (2019a). Furthermore, we also tested the impact of the interactive term of governance and ODA on HDI and reported the result in Table 9.

The impact of energy intensity is negative and significant on HDI in the short and long run for all specifications. The interactive term of ODA and governance has a positive and significant impact on HDI in the short run for all countries and a positive and significant impact in the long run for low-income countries. This result highlights the central role played by governance in annihilating the negative impact of ODA on human development through better management of this aid, an assessment of projects to be financed, and rigorous monitoring. This result is in line with the findings of Lee et al. (2019) who suggested that the outcome of ODA programs depends on state bureaucracies and effective collaboration among nations. Table 10 reports the result of the CS ARDL estimations using the interactive term of ODA and carbon emissions. As shown by the estimated output there is a positive and significant relationship between the interactive term and HDI. However, as shown by D. D. Li et al. (2021) green ODA<sup>5</sup> can reduce the negative impact of carbon emissions if combined with good institutions. Thus, for ODA through carbon emissions reduction to help achieve human development, it is essential to have strong institutions.

**Table 8.** Robustness check with the interactive term Gov\_co2.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI
SHORT RUN						
L.lnHDI	0.442*** (0.000)		0.404*** (0.000)		0.460*** (0.000)	
lnGov_co2	0.020 (0.219)	−0.000 (0.993)	0.021 (0.150)	−0.008 (0.517)	0.024 (0.408)	0.031* (0.053)
D.lnODAnet	−0.001** (0.042)	−0.000 (0.412)	0.0001 (0.870)	0.001 (0.139)	−0.0027** (0.019)	−0.002* (0.083)
D.lnene_int	−0.002** (0.011)	−0.001* (0.094)	−0.001 (0.147)	−0.002* (0.062)	−0.003** (0.026)	−0.002 (0.110)
LONG RUN						
lr_lnODAnet	−0.003 (0.135)	0.000 (0.950)	−0.001 (0.431)	0.001 (0.554)	−0.003 (0.446)	−0.002 (0.452)
lr_lnene_int	−0.006** (0.038)	−0.003 (0.274)	0.001 (0.680)	−0.005 (0.181)	−0.014** (0.016)	−0.000 (0.796)
lr_lngov_co2	0.025 (0.610)	0.050** (0.028)	0.017 (0.763)	0.004 (0.872)	0.014 (0.877)	0.101*** (0.001)
ECT	−0.558*** (0.000)	−0.544*** (0.000)	−0.596*** (0.000)	−0.58*** (0.000)	−0.540*** (0.000)	−0.562*** (0.000)
Observations	840	840	405	405	435	435
R-squared	0.318		0.367		0.291	
Number of countries	56	56	27	27	29	29

Note. pval in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

**Table 9.** CS ARDL estimation with an interactive term of ODA and governance.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI
SHORT RUN						
L.lnHDI	0.463*** (0.000)		0.421*** (0.000)		0.477*** (0.000)	
D.Inc02emission	0.054** (0.037)	0.059* (0.091)	0.062* (0.084)	0.058 (0.167)	0.046 (0.230)	0.042 (0.411)
D.Ingov_oda	0.000* (0.064)	0.000 (0.832)	0.000 (0.165)	0.000 (0.223)	0.000 (0.137)	0.000 (0.304)
D.Inene_int	−0.004*** (0.000)	−0.004*** (0.001)	−0.003** (0.010)	−0.003* (0.064)	−0.005** (0.012)	−0.006*** (0.007)
LONG RUN						
lr_Inc02emission	0.661 (0.218)	0.147*** (0.009)	−12.94 (0.331)	0.225*** (0.000)	0.083 (0.669)	0.036 (0.657)
lr_Inene_int	−0.016*** (0.003)	−0.009*** (0.004)	0.064 (0.390)	−0.013** (0.026)	−0.023** (0.016)	−0.005* (0.092)
lr_Ingov_oda	0.003 (0.353)	0.001 (0.102)	−0.095 (0.297)	0.000 (0.327)	0.000 (0.730)	0.001* (0.068)
ECT	−0.537*** (0.000)	−0.591*** (0.000)	−0.579*** (0.000)	−0.61*** (0.000)	−0.523*** (0.000)	−0.641*** (0.000)
Observations	840	840.	405	405.	435	435.
R-squared	0.321		0.367		0.293	
Number of groups	56	56	27	27	29	29

Note. pval in parentheses\*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

Table 11 reports the results of the estimations of the regressors on life expectancy. Energy intensity, reflecting how much energy is required to produce one unit of output, has a negative and significant impact on life expectancy in the short run for all countries but also low-income countries. This result reflects how the accessibility of energy sources and better management of the latter, are key factors for enhancing human development through human health. Chen et al. (2021) showed that generating energy from fossil fuels leads to an increase in carbon emissions and thus, harms human health while renewable energy use has a positive impact on human health. These findings emphasize how renewable energy outperforms non-renewable energy because it has a positive impact on life expectancy and enhances the environment quality. However, Polcyn et al. (2023) found that an increase in overall energy consumption leads to better human health. Carbon emission has a positive impact on life expectancy in the long run. Most of the time in developing countries an increase in carbon emissions reflects economic growth. Moreover, as suggested by Polcyn et al. (2023) increasing public health expenditure led

**Table 10.** CS ARDL with interactive term of ODA and carbon emissions.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) lnHDI	(AMG) lnHDI	(CS ARDL) lnHDI	(AMG) lnHDI	(HDI) lnHDI	(AMG) lnHDI
SHORT RUN						
L.lnHDI	0.371*** (0.000)		0.335*** (0.000)		0.425*** (0.000)	
D.lnoda_co2	0.000 (0.822)	−0.000 (0.902)	0.000 (0.715)	0.004* (0.083)	0.000 (0.845)	−0.005 (0.223)
D.Ingov_effect	0.002 (0.206)	0.000 (0.557)	0.001 (0.651)	0.001 (0.629)	0.004* (0.086)	0.003 (0.112)
D.Inene_int	−0.002** (0.013)	−0.002** (0.039)	−0.001 (0.132)	−0.003** (0.026)	−0.002** (0.039)	−0.002 (0.190)
LONG RUN						
lr_lnoda_co2	0.000 (0.898)	−0.003 (0.590)	0.006 (0.300)	0.006 (0.206)	0.002 (0.759)	−0.016* (0.083)
lr_Ingov_effect	0.006 (0.232)	0.004 (0.207)	−0.001 (0.915)	0.005 (0.238)	0.009 (0.179)	0.004 (0.365)
lr_Inene_int	−0.003* (0.082)	−0.002 (0.506)	−0.001 (0.764)	−0.006* (0.067)	−0.008** (0.010)	0.002 (0.681)
ECT	−0.629*** (0.000)	−0.600*** (0.000)	−0.665*** (0.000)	−0.67*** (0.000)	−0.575*** (0.000)	−0.598*** (0.000)
Observations	840	840.	405	405.	435	435
R-squared	0.318		0.343		0.312	
Number of countries	56	56	27	27	29	29

Note. pval in parentheses\*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

**Table 11.** Estimations of the regressors on life expectancy.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) Lnlife	(AMG) Lnlife	(CS ARDL) Lnlife	(AMG) Lnlife	(CS ARDL) Lnlife	(AMG) Lnlife
SHORT RUN						
L.lnlife_expect	0.878*** (0.000)		0.897*** (0.000)		1.071*** (0.000)	
D.lnc02emission	0.008 (0.574)	0.001 (0.924)	−0.003 (0.338)	0.010 (0.217)	0.026 (0.450)	−0.010 (0.776)
D.lnODAnet	0.000 (0.192)	0.000 (0.818)	−0.000 (0.426)	−0.000 (0.827)	0.000 (0.127)	0.000 (0.550)
D.lngov_effect	−0.003 (0.230)	0.000 (0.741)	0.001 (0.387)	0.001 (0.538)	−0.007 (0.211)	−0.000 (0.807)
D.lnene_int	0.000 (0.462)	−0.000* (0.078)	0.000 (0.514)	−0.000 (0.248)	−0.000 (0.727)	−0.001* (0.073)
LONG RUN						
lr_lnc02emission	0.012 (0.887)	0.193 (0.156)	0.017 (0.957)	0.094* (0.082)	−0.106 (0.409)	−0.035 (0.855)
lr_lnODAnet	−0.000 (0.625)	0.002 (0.433)	0.014 (0.159)	0.000 (0.695)	0.000 (0.608)	0.000 (0.874)
lr_lngov_effect	0.000 (0.935)	0.000 (0.893)	−0.319 (0.270)	−0.001 (0.768)	0.014 (0.387)	0.007 (0.482)
lr_lnene_int	−0.000 (0.392)	−0.002 (0.714)	0.027 (0.556)	−0.003 (0.192)	−0.001 (0.730)	0.003 (0.749)
ECT	−0.122** (0.022)	−0.107*** (0.000)	−0.103 (0.115)	−0.221*** (0.000)	−0.071 (0.307)	−0.126** (0.016)
Observations	840	840	405	.405	435	.435
R-squared	0.056		0.217		0.051	
Number of countries	56	56	27	27	29	29

Note. pval in parentheses\*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

to better human health. Thus, the carbon emissions positive effect on life expectancy can be explained by the fact that an increase in carbon emissions reflects economic growth which in turn can lead to an increase in health care expenditure. However, Emodi et al. (2022) found that carbon emissions harm human health and thus emphasized how detrimental dioxide carbon emissions are to human health.

Table 12 displays the results of the estimations of the regressors on national income. Carbon emissions have a positive and significant impact on national income in the short and long run. Otim et al. (2022) showed that there is a causality running from economic growth to carbon emissions. This finding suggests that increasing economic growth leads to more pollution. Begum et al. (2015) contradict this finding and suggest that increasing economic growth leads to less carbon emissions. However, this mitigated carbon emissions and economic growth relationship highlights how renewable energies are paramount for reaching sustainable development. Governance effectiveness has a positive impact on national income in the long and short run while energy intensity has a negative impact. The negative impact of energy intensity, reflecting the required energy for one unit output, on national income, reflects how better management of energy sources can contribute to economic growth. According to Abdollahi (2020) energy consumption is a key driver of economic development in developing countries. Increasing energy consumption leads to more pollution and thus can penalize sustainable development. However, as suggested by Dada and Akinlo (2021) institutional quality can moderate environmental pollution. Official development assistance has a negative impact on national income in the short run. This result is in contradiction with the finding of Kwablah et al. (2014) who found that foreign aid has a positive impact on national income.

Table 13 displays the results of the estimations of the regressors on expected years of schooling. Official development assistance has a negative and significant impact on expected years of schooling in the short and long run. The results found reflect how better management of assistance received can positively affect human development. This negative impact is in contradiction with Lee et al. (2019) who found that total official assistance has a positive impact on education. However, as suggested by Yiheyis and Woldemariam (2020) the intensity of the effect of official assistance depends on multiple factors specific to the receiving country such as the quality of institutions, and the degree of instability of aid flows. Energy intensity has a negative and significant impact on expected years of schooling in the short and long run. As shown by Bridge et al. (2016), electricity access has a positive impact on educational attainment. Moreover, Zafar et al. (2020) found a bidirectional causality between renewable energy consumption and education.

**Table 12.** Estimation of the regressors on national income.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) Lngross_inc	(AMG) Lngross_in	(CS ARDL) Lngross_inc	(AMG) Lngross_Inc	(CS ARDL) Lngross_inc	(AMG) Lngross_in
<b>SHORT RUN</b>						
L.Ingros_inco	0.649*** (0.000)		0.636*** (0.000)		0.695*** (0.000)	
D.Inc02emission	0.256* (0.088)	0.228 (0.389)	0.093 (0.509)	0.107 (0.818)	0.405 (0.127)	0.354 (0.200)
D.InODAnet	-0.005 (0.388)	-0.009* (0.076)	-0.006 (0.541)	-0.000 (0.943)	-0.003 (0.583)	-0.010* (0.072)
D.Ingov_effect	0.059*** (0.000)	0.027* (0.065)	0.035* (0.088)	0.035* (0.051)	0.076*** (0.000)	0.012 (0.554)
D.Inene_int	-0.051*** (0.000)	-0.048*** (0.000)	-0.036*** (0.000)	-0.035 (0.200)	-0.065*** (0.000)	-0.063*** (0.000)
<b>LONG RUN</b>						
lr_Inc02emission	1.340 (0.192)	0.056 (0.829)	-0.691 (0.580)	0.908*** (0.006)	2.44** (0.026)	-0.524 (0.110)
lr_InODAnet	-0.105 (0.638)	-0.009 (0.293)	-0.107 (0.280)	-0.006 (0.496)	-0.006 (0.846)	-0.004 (0.755)
lr_Ingov_effect	-0.253 (0.573)	0.052*** (0.008)	-0.070 (0.806)	0.061** (0.013)	0.330*** (0.000)	0.047 (0.132)
lr_Inene_int	0.061 (0.861)	-0.051*** (0.000)	-0.108 (0.172)	-0.059*** (0.004)	-0.257*** (0.001)	-0.046*** (0.001)
ECT	-0.351*** (0.000)	-0.616*** (0.000)	-0.364*** (0.000)	-0.651*** (0.000)	-0.305*** (0.000)	-0.590*** (0.000)
Observations	840	840	405	405	435	435
R-squared	0.212		0.256		0.189	
Number of countries	56	56	27	27	29	29

Note. pval in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

**Table 13.** Estimation of the regressors on expected years of schooling.

VARIABLES	ALL COUNTRIES		MIDDLE INCOME		LOW INCOME	
	(CS ARDL) Lnexpect_school	(AMG) Lnexpect_school	(CS ARDL) Lnexpect_school	(AMG) Lnexpect_school	(CS ARDL) Lnexpect_school	(AMG) Lnexpect_school
<b>SHORT RUN</b>						
L.Lnexpect_school	0.555*** (0.000)		0.560*** (0.000)		0.519*** (0.000)	
D.Inc02emission	0.119 (0.265)	0.286** (0.023)	0.300** (0.012)	0.250 (0.115)	-0.053 (0.742)	0.160 (0.304)
D.InODAnet	-0.011** (0.024)	-0.011*** (0.006)	-0.002 (0.509)	-0.006 (0.119)	-0.016* (0.071)	-0.015** (0.019)
D.Ingov_effect	0.005 (0.671)	-0.010 (0.299)	-0.003 (0.828)	-0.018* (0.090)	0.021 (0.183)	0.019 (0.275)
D.Inene_int	-0.009* (0.089)	-0.022*** (0.001)	-0.015** (0.040)	-0.018* (0.064)	-0.006 (0.427)	-0.020** (0.011)
<b>LONG RUN</b>						
lr_Inc02emission	-17.10 (0.236)	0.567* (0.063)	1.241 (0.223)	1.018** (0.015)	-0.669 (0.360)	0.156 (0.676)
lr_InODAnet	0.118 (0.465)	-0.004 (0.564)	-0.043** (0.021)	-0.0018 (0.847)	0.060 (0.374)	-0.014 (0.173)
lr_Ingov_effect	-0.811 (0.326)	0.045** (0.045)	0.000 (0.995)	0.021 (0.390)	-0.026 (0.557)	0.0716** (0.032)
lr_Inene_int	0.263 (0.115)	-0.035* (0.073)	-0.020 (0.575)	-0.080** (0.021)	-0.002 (0.920)	0.007 (0.589)
ECT	-0.445*** (0.000)	-0.556*** (0.000)	-0.440*** (0.000)	-0.592*** (0.000)	-0.481*** (0.000)	-0.606*** (0.000)
Observations	840	.840	405	.405	435	435
R-squared	0.341		0.303		0.378	
Number of countries	56	56	27	27	29	29

Note. pval in parentheses \*\*\* $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ ; lr long run, D.first difference, L. lag.

#### 4.1. Discussion of the results

The paper analyzed the nexus between human development, official development assistance (ODA), governance, and carbon emissions. The findings showed that ODA has a negative and significant impact on HDI while governance and carbon emissions have a positive and significant impact. Energy intensity, indicating how much energy is required to produce one unit of output, harms human development. The

negative impact of ODA in developing countries reflects mismanagement but also the complexity of the conditions linked to obtaining assistance. As suggested by Killick et al. (1998), conditionality related to aid allocation failed to induce policy reform in developing countries. For Schedler et al. (1999) the donors have overestimated their power to induce policy reform in a very low policy environment and have neglected domestic politics. Moreover, as suggested by C. Burnside and Dollar (2000), aid effectiveness is affected by the various policy distortions, how it is used (invested), and what motivates this investment. This shows the importance of close collaboration between donors and the countries receiving aid to optimize its performance. In addition, this result reflects the importance of prioritizing the allocation of aid based on the 'recipient's needs' (RN) theory to reduce the development gap between countries to facilitate exchanges. This finding is in line with Narteh-Yoe et al. (2023) who found that aid harms economic growth in poor countries. However, other researchers suggested that the effect of aid depends on the amount of aid that a country receives. Asongu et al. (2019) found that when foreign aid is between 60 and 150 (% of GDP) it has a positive effect on inclusive human development.

The positive impact of carbon emissions on human development is in line with the EKC (environmental Kuznet curve) hypothesis. This theory suggests that environmental pollution increases in the first stages of economic growth which is the case in developing countries. This result is in line with Aqib and Zaman (2023) who found that economic growth causes carbon emissions on the one hand while increasing life expectancy on the other hand. In the same vein, Sheraz et al. (2021) showed that GDP and energy consumption increased carbon emissions. However, this positive correlation between carbon emissions and human development depends on the level of development. For Steinberger et al. (2012) the relationship between carbon emission and human development depends on the income level of the nation. The positive impact of governance on human development reflects the key role played by institutions in the development process. Moreover, Fukuyama (2019) suggested that building a strong state is a prerequisite for economic growth. For the author, the Korean government had a paramount role in the development process through its interventions. In this vein, Asongu et al. (2019) showed that good governance had a positive impact on inclusive development in sub-Saharan African countries.

The findings show that the combination of governance and development assistance has a positive impact on human development. The same positive impact is found for the combination of governance and carbon emissions. As suggested by Isham et al. (1997) good governance leads to greater institutional effectiveness and, more efficient resource allocation. Rodrik (2000) showed that government responsiveness to shocks depends on institutional quality. In addition, the authors emphasized the paramount role played by government officials in aid effectiveness given their responsibility in terms of aid management. The results are in line with Yiheyis and Woldemariam (2020) who found that the effectiveness of foreign aid, and climate change mitigation depended on the quality of institutions. However, for Hansen and Tarp (2001) the impact of aid on growth doesn't depend on good policies. In the same vein, Asongu and Nnanna (2019) found that governance mitigated the negative impact of carbon emissions on inclusive human development.

The development assistance harms expected years of schooling while governance has a positive impact. Official development assistance harms national income while governance has a positive one. Carbon emissions have a positive impact on life expectancy. In the literature, the impact of official development assistance is mitigated. Ozigbu (2018) showed that technical cooperation grant exerts a significant positive impact on human development in Nigeria in both the short and long run while net ODA received harms human development indicators in the short run. Asongu et al. (2019) concluded that countries with a low level of development needed substantial funding to reach inclusive development suggesting that aid effectiveness is conditional to the level of development. Moreover, other researchers showed that the quality of institutions can moderate the impact of aid. As Yiheyis and Woldemariam (2020) suggested, the effectiveness of foreign aid and the achievement of the other SDGs for sustainable human development depends on the quality of institutions. Hashem (2019) found that there is a significant relationship between governance and human development. In addition, the impact of carbon emissions on life expectancy reflects the positive link between CO<sub>2</sub> emissions and economic growth. The same positive link has been found by Aqib and Zaman (2023) who suggested that economic growth caused carbon emissions on the one hand while increasing life expectancy on the other hand.



## 5. Conclusion

Sustainable development, measured by Human Development Index (HDI), is the main goal of United Nations state members. Moreover, achieving this objective of sustainable development requires that, in addition to sustained economic growth, the well-being of individuals be put at the forefront, all this without jeopardizing the environment. For developing countries, following the various crises that have shaken the world with the latest covid 19, experiencing sustained economic growth remains difficult. Add to this the complexity of the relationship between sustainable development and economic growth requiring coordination and cooperation between developed and developing nations. In pursuit of the common objective of all nations, which is sustainable development, the institutions of developing countries play a central role. This role can range from the development, implementation, and monitoring of various policies to the optimal management of the country's resources. This is how it becomes more than necessary to analyze how cooperation through development assistance, the efficiency of institutions, and the protection of the environment through the reduction of carbon emissions interact with human development. This analysis will allow the decision-makers of these countries to better orient policies but also to optimize cooperation with their partners. This study contributes to this analysis using data on 56 developing countries, 29 low-income countries, and 27 middle-income, spanning from 2005 to 2019. Different approaches were used. Cross-sectionally augmented ARDL and the AMG (Augmented Mean Group) were used to analyze the long- and short-term relationship. We used interactive terms to assess the effect of the combination of different factors on development as well as to check the robustness of the results. In addition, we divided the human development index based on its dimensions to assess the impact of the independent variables on them.

The results showed that, considering all countries, official development assistance (ODA) has a negative and significant impact on HDI while governance and carbon emissions have a positive and significant impact. However, the combination of governance and development assistance has a positive impact on human development. The same positive impact is found for the combination of governance and carbon emissions. Despite the negative impact on human development of ODA, the association of the latter with governance promotes human development and thereby the achievement of the SDGs (sustainable development goals) in particular SDG 1 'no poverty', SDG 3 'good health and well-being', SDG 4 'quality education', and SDG 8 'decent work and economic growth'. Moreover, human development in developing countries requires the achievement of SDG 16 'peace, justice and strong institutions' but also the association of the latter with SDG 17 'partnerships for the goals'. In addition, the positive impact of the combination of governance and carbon emissions on human development highlights the moderating role of good institutions. The latter allows developing countries, which are often on the ascending phase of the Kuznet curve, to optimize their production without significantly affecting the state of the environment. Thus, the achievement of SDG 16 'peace, justice and strong institutions' associated with an increase in carbon emissions reflecting the achievement of SDG 8 'decent work and economic growth' promotes human development for developing countries.

For low-income countries, the findings showed that official development assistance has a negative impact on human development while governance effectiveness has a positive one. The combination of governance effectiveness and official development assistance has a positive impact on human development. The same positive impact is found for the combination of governance and carbon emissions on human development. Moreover, we assessed the impact of the explanatory variables on the main dimensions of the human development index. Official development assistance has a negative impact on national income while governance and carbon emissions have a positive one. Official development assistance has a negative impact on the expected years of schooling while governance has a positive one. The findings emphasize the central role played by good institutions in the realization of sustainable development goals through human development improvement. We recommend that decision-makers in low-income countries prioritize the achievement of SDG 16 'peace, justice and strong institutions' and use this objective as a central piece in the achievement of other SDGs, particularly by fighting corruption in all its forms. We recommend as a priority an analysis of the real needs of every country considering its factor endowment not only for the elaboration of good policies but also for the optimal allocation of resources. This analysis will aim to achieve SDG 8 'decent work and economic growth' often accompanied by an increase in carbon emissions in developing countries. Furthermore, whether for the achievement of SDG 16, SDG 8, environmental protection, or even for other SDGs, low-income countries need cooperation with other countries, reflecting the importance of SDG 17 'partnerships for the

goals'. We recommend that partners of developing countries ease the conditions for obtaining assistance. These conditions are often untenable and contribute to making aid ineffective. The consideration of the needs of the countries receiving assistance from the donors for a better allocation of aid must constitute the basis of this cooperation.

For middle-income countries, the findings showed that carbon emissions have a positive impact on human development. The combination of carbon emissions and official development assistance has a positive impact on human development. Moreover, we divided human development based on its main dimensions to assess the impact of independent variables on them. Carbon emissions have a positive impact on life expectancy. Governance and carbon emissions have a positive impact on national income. Carbon emissions have a positive impact on the expected years of schooling while official development assistance has a negative one. For middle-income countries, carbon emissions, characterizing an increase in economic activity, constitute an important indicator of economic growth for these countries. Thus, an increase in economic activity (reflecting the achievement of SDG 8 'decent work and economic growth') materialized by the increase in carbon emissions positively affects the achievement of SDG 1 'no poverty', SDG 3 'good health and well-being', and SDG 4 'quality education'. We recommend that policymakers of middle-income countries focus on the realization of SDG 8 'decent work and economic growth' and use this objective as a central piece in the achievement of other SDGs for human development. Middle-income countries have already reached a certain level of development, we recommend to decision-makers in these countries the association of SDG 8 and SDG 17 'partnerships for the goals' (materializing international cooperation) to further optimize human development. In other words, for these middle-income countries, cooperation with other countries, particularly through ODAs, makes it possible to further increase production and thus human development. Furthermore, given the importance of sustainable economic growth, we recommend to middle-income countries' policymakers the orientation of SDG 17 towards technology transfer to reduce as much as possible the weight of economic growth on the environment. In addition, we recommend the implementation of a more rigorous Global environmental policy aimed at reducing carbon emissions. A policy that will impose a higher tax on gas emissions in advanced countries while guaranteeing compensation to developing countries for reducing their gas emissions.

However, this research is limited by data availability in developing countries which forces researchers to resort to secondary data and limits the number of variables that can be used for the study. In addition, for future research, we recommend the use of a threshold model that can consider the non-linearity of the relationship with development to compare the results of the latter with those of linear models and thus be able to formulate better policy recommendations.

## Notes

1. <https://databank.worldbank.org/source/world-development-indicators>.
2. <https://databank.worldbank.org/source/worldwide-governance-indicators>.
3. <https://hdr.undp.org/data-center/human-development-index#/indicies/HDI>.
4. <https://data.oecd.org/oda/net-oda.htm>.
5. Green aid or green Overseas Development Assistance (ODA) focuses on the reduction of carbon emissions by encouraging increased investment in efficient energy technologies, energy-saving facilities, CO<sub>2</sub> reservoirs and/or the production of renewable energy.

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## Author contribution

Jean Tony Ezako did all the work related to this research paper. Designed the research, did the required investigations, analyzed the data, and wrote the paper.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## About the author



**Jean Tony Ezako**, Burundian citizen, holder of a bachelor's degree from the Faculty of Economics and Management of the University of BURUNDI. Moreover, I am passionate about economic research with the aim of contributing to the development of my country, Burundi, and developing countries in general. Thus, this paper on "The nexus between HUMAN DEVELOPMENT, Official development assistance, carbon emissions, and governance in developing countries for the realization of sustainable development goals" is part of a research project consisting of 4 papers that I initiated to focus on the role of financial economics in the development process. The other 3 papers are; analyze of inflation and economic growth relationship in Burundi: Analysis of Official Development Assistance and Total Factor Production relationship in developing countries: Analysis of globalisation and Total Factor Production relationship in developing countries.

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## Data availability statement

Data available at request to the author.

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## Appendix A

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### Country name

1. Angola 2. Bangladesh 3. Benin 4. Bhutan 5. Bosnia and Herzegovina 6. Burkina Faso 7. Cambodia 8. Cameroon 9. Colombia 10. Congo, Dem. Rep. 11. Costa Rica 12. Cote d'Ivoire 13. Dominican Republic 14. Ecuador 15. Egypt, Arab Rep. 16. El Salvador 17. Ethiopia 18. Fiji 19. Ghana 20. Guatemala 21. Haiti 22. Honduras 23. India 24. Iran, Islamic Rep. 25. Iraq 26. Jordan 27. Kazakhstan 28. Kenya 29. Kyrgyz Republic 30. Lebanon 31. Madagascar 32. Malawi 33. Mali 34. Mauritania 35. Moldova 36. Mongolia 37. Morocco 38. Mozambique 39. Myanmar 40. Namibia 41. Nepal 42. Nicaragua 43. Nigeria 44. Pakistan 45. Rwanda 46. Senegal 47. South Africa 48. Tajikistan 49. Tanzania 50. Tunisia 51. Uganda 52. Uzbekistan 53. Vietnam 54. Zambia 55. Zimbabwe 56. Albania

### Low-income countries

1. Angola 2. Benin 3. Bhutan 4. Burkina Faso 5. Cameroon 6. Congo, Dem. Rep. 7. Cote d'Ivoire 8. Dominican Republic 9. El Salvador 10. Ethiopia 11. Ghana 12. Guatemala 13. Haiti 14. Jordan 15. Kenya 16. Kyrgyz Republic 17. Madagascar 18. Malawi 19. Mali 20. Mauritania 21. Mongolia 22. Mozambique 23. Namibia 24. Rwanda 25. Senegal 26. Tanzania 27. Uganda 28. Zambia 29. Zimbabwe

### Middle-income countries

1. Albania 2. Bangladesh 3. Bosnia and Herzegovina 4. Cambodia 5. Colombia 6. Costa Rica 7. Ecuador 8. Egypt, Arab Rep. 9. Fiji 10. Honduras 11. India 12. Iran, Islamic Rep. 13. Iraq 14. Kazakhstan 15. Lebanon 16. Moldova 17. Morocco 18. Myanmar 19. Nepal 20. Nicaragua 21. Nigeria 22. Pakistan 23. South Africa 24. Tajikistan 25. Tunisia 26. Uzbekistan 27. Vietnam

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