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THE IMPACT ASSESSMENT OF SUSTAINABLE DEVELOPMENT ASSISTANCE ON CARBON DIOXIDE EMISSIONS: THE SUB-SAHARAN AFRICA EXPERIENCE

[1]Carren Pindiriri and [2]Clainos Chidoko
[1]Department of Economics, University of Zimbabwe, Zimbabwe
[2]Department of Economics, Great Zimbabwe University, Zimbabwe

ABSTRACT
The world is facing environmental challenges in particular the surging growth of greenhouse gases emissions. In line with these challenges, the developed world is funding sustainable development in poor countries, assumed to have low willingness to pay for environmental quality improvements. The study attempts to examine whether financial development assistance reduces carbon dioxide emissions in Sub-Saharan Africa (SSA) or not. Empirically, the study estimates the random effects panel data model in two functional forms, the linear and the quadratic forms, linking carbon dioxide emissions to sustainable development assistance, per capita income, energy use and manufacturing share. The study findings provide evidence that the quadratic functional form in terms of the sustainable development assistance variable provides the best fit for SSA data. While the explicit link between environmental quality and per capita income professed by various empirical studies is not refuted, the study finds evidence that increases in current per capita incomes increase carbon dioxide emissions in SSA. But in the dynamic random effects estimation, the study finds no evidence of a significant influence of previous carbon dioxide emissions on current emissions although there is an indication of a positive relationship.

Keywords: Carbon dioxide (CO_2) emission, Panel data, Post-cure financing, Pre-cure financing, Projections, Sustainable Development Assistance

INTRODUCTION

Global warming has become the major challenge of the world today. Average global temperatures are rising to unprecedented levels due to unsustainable burning of fossils in production, with some countries experiencing deaths from heat waves. Human economic activities that emit greenhouse gases are behind the deterioration of the environmental quality. The United Nations Environmental Programme (UNEP)'s annual report (2007) reports that the United Nations (UN) has convened several conferences to discuss the challenge of climate change. In 2002, several nations met in Kyoto, Japan and launched the Kyoto Protocol, which sets international standards for reducing global greenhouse gases emissions levels. The Kyoto Protocol was set to expire in 2012 and in December 2007, countries converged in Bali, Indonesia for the UN Framework Convention on Climate Change (UNFCCC) conference, which launched international negotiations to draft a successor treaty to Kyoto Protocol. The Bali conference created the road map, which committed nations to negotiating a new climate change treaty.

Economic growth is highly linked with increasing emissions of CO_2. In developing countries, rapid economic growth is not an option but a need because of the starving populations. It is against this background that though every individual country should have an input in the reduction of greenhouse gases emissions through sustainable economic development, developing countries tend to prioritise economic growth at the expense of environmental air quality improvements. A holistic approach in which the rich compensate the poor for emissions reduction is therefore a prerequisite for the global fight against greenhouse gases emissions. Developed countries have since been providing sustainable development assistance to developing countries for the purpose of achieving sustainable development. However, the question is, "Does the assistance effectively influence CO_2 in poor countries?"

The study seeks to empirically examine the contribution of sustainable development assistance given to developing countries in improving environmental air quality. It specifically investigates how the financial Sustainable Development Assistance (SDA) given to Sub-Saharan Africa (SSA) has influenced its CO_2 emissions over the period 1970 to 2000.
It also investigates the impact of energy use intensity, per capita income and manufacturing share on CO_2 emissions in SSA.

The theoretical basis of this study is that in the absence of compensation from rich countries, poor countries devote insignificant resources to control CO_2 emissions because their Willingness to Pay (WTP) for environmental air quality improvements is very low. Willingness to Pay (WTP) is the cost that an individual is willing to incur in order to get a unit of the required product. On the other hand, in the presence of compensation for their loss of output (the opportunity cost of environmental air quality improvements), they will devote significant resources to environmental quality. But because of the absence of perfect monitoring, it is assumed that the compensation given in the form of financial assistance such as SDA can only influence emissions weakly in these countries due to moral hazard problems. So the study tests the assertion that financial SDA negatively and weakly explains the variability of carbon dioxide emissions in developing countries. In addition, it also tests the hypothesis of a positive relationship between CO_2 emissions and the other explanatory variables, which include energy use intensity, per capita income and manufacturing share.

The study covers a sample of 28 SSA countries over a 31-year period from 1970 to 2000. The two dimensional model (time dimension and cross sectional or country dimension) calls for the use of panel data methodology. By applying this methodology, the study seeks to explain the effect of financial SDA on CO_2 emissions variability across SSA countries over time. It focuses on whether financial SDA influences CO_2 emissions in SSA countries and not on the causes of the effectiveness/ineffectiveness of SDA.

BACKGROUND

Euro Statistics (2008) indicate that in Western Europe, five countries namely Germany, the United Kingdom, Italy, France and Spain are among the top 20 national fossil fuel CO_2 emitters. In 2004, North America comprising of the United States (US) and Canada was the highest fossil fuel CO_2 emitting region of the world with 1.82 billion tons of carbon as reported by WBDIS (2007). It was a 1.6% increase from the 2003 figure. But because of rapid growth in other economies like China, emissions from North America have shrunk from 46.4% of the global total in 1950 to 24.3% in 2004. The WBDIS (2007) further reports that the second world economies, like China have experienced rapid growth in green house gases emissions. Growth in CO_2 emissions in China was virtually continuous until 1996 as the centrally planned Asia's contribution rose from 1.4% of the world total emissions in 1950 to 15.6% in 1996 and to over 20% in 2006.

Unlike in developed countries and second world economies, the WBDIS (2007) show that Africa's fossil fuel CO_2 emissions are low in both absolute and per capita terms. Total emissions for Africa have increased 12.1 fold since 1950 reaching 314 million metric tons of carbon in 2004, but still less than the emissions of some single nations including the US, China, Russia and Japan among others. Emissions from all fuel sources have grown in the African region over time with liquid fuels accounting for 44%, solid fuels accounting for 34.2%, and gas fuels accounting for 12.4%. South Africa alone accounts for over 30% of the total continental emissions from fossil fuels and cement production.

The general consensus in most poor countries is that they should not be too concerned about greenhouse gases emissions while their populations are starving. Their economies are still poor to the extent that fuel and cement production (CO_2 emitting processes) are considered essential for economic growth. These economies also argue that though their total emissions are growing, they still make an insignificant share of the world's total emissions. On the basis of this reasoning, developing countries have been so reluctant in devoting significant resources to fighting the surging growth of greenhouse gases emissions. However, it is feared that since developing countries will in the future reach the current Chinese phase of economic growth and the developed world phase, with the current levels of emissions the environment will not have the capacity to sustain life.

While the deterioration of the environmental air quality has become a major concern in most developed countries in particular the European Union (EU), the USA and Japan, it has not been considered a special issue in most developing countries. Developing countries argue that they do not have enough resources to finance environmental air quality improvements given their very low output levels, insignificant world share of greenhouse gases emissions and starving populations. In the environmental economics literature (Kolstad, 2000), it is argued that the poor have very low willingness to pay for environmental quality improvements while the rich's WTP for environmental quality is high. Kolstad further argues that the rich whose WTP is very high should compensate the poor for the incurred opportunity cost of environmental quality improvements in order to instil interest in the poor for environmental quality investment. In support of this argument, the flow of financial assistance for sustainable development from rich countries to poor countries has increased over the past years.

The UNEP annual report (2007) reports that a joint UNEP-World Bank initiative, "Carbon Finance for Sustainable Energy in Africa (CFSEA)" is working with host government agencies, banks and project sponsors to develop an initial pipeline of Clean Development Mechanism (CDM) investment opportunities in Cameroon, Ghana, Mali, Mozambique and Zambia. UNEP is working with funding from Sweden, Spain and Finland to overcome barriers to the carbon market in SSA countries and enhance the capacity of the private sector to access carbon finance. The 2007 WBDIS indicates that in 1998 ODA to SSA fell from the 1994 figure of US$18.8 billion to US$13.5 billion. Since it had the greatest share of the total SDA to SSA, its fall caused the total SDA to SSA to fall to US$12.3 billion in 1999 from the 1990 figure of US$17.2 billion, despite the fact that US aid, which is mostly humanitarian, was increasing during this period.

During the period of increasing inflow of SDA, the Gross Domestic Product (GDP) per capita was also increasing but at a very slow rate. During the period 1983 to 1999 in which SDA per capita was increasing rapidly in the SSA region, GDP per capita or economic growth failed to respond to SDA growth. In fact economic growth remained stable in most years, with unpronounced positive and negative growth rates in some years. The African Development Bank's annual report (2004) reports that over 30% of the aid to SSA in the 1980s and early 90s were allocated to countries with instability like Mozambique, Rwanda, Angola, Ethiopia, Somalia, among others. The aid was basically for humanitarian issues and failed to address investment issues in both output production and environmental technologies.

Despite the increasing total green-house gases emissions in SSA, per capita emissions almost remained stable from 1970 to 2000.

THEORETICAL FRAMEWORK

Little has been said about the applicability of classical models in explaining the impact of financial sustainable development assistance on environmental quality in poor countries. There is wide agreement about the need for developed countries to assist developing countries with financial resources for the purpose of achieving the world‘s developmental goal of sustainability. There is however least agreement on whether the financial assistance is efficiently used by developing countries or whether the assistance is effectively provided by the developed countries. What does economic theory say about this?

The Theory of Utility Maximization

The basic tool of analysis in this paper is the consumer theory of utility maximization. When developing countries receive financial SDA from developed countries they respond by attempting to maximize their utility subject to their resource base. However, the question is: "how do these countries allocate the financial SDA to maximize their utility?" They can either finance environmental air quality improvements activities, output growth activities or both. The objective of developed countries giving sustainable development financial assistance to these countries is to finance activities that improve developing countries' output (Y) without harming the environmental quality (Q).

Outcome expectations from developed countries might be higher than the optimal outcomes for environmental air quality in developing countries as explained by the low level of WTP for improvements in environmental air quality in poor countries. It is assumed that the indifference curves for poor countries are biased towards output growth whereas those of developed countries are biased towards environmental quality. In most low income countries like in SSA countries, governments strive to feed the majority poor population, a situation which could force these governments to use the cheapest means of production in order to provide affordable products to this group whose WTP for environmental air quality is very low. In the event that the government's utility is more biased towards output growth than the country's utility, the environmental quality and output outcomes from financial SDA might also be non-optimal. The inefficiency of financial SDA in developing countries might therefore be a result of:

- Developed countries demanding higher than optimal environmental quality outcomes from developing countries.
- Abuse of financial SDA by developing countries' governments which might be seeking to satisfy government utility at the expense of country utility.

The abuse of financial SDA is mainly a result of moral hazard problem. Governments of developing countries can only abuse the assistance in situations where the providers of the assistance cannot monitor the actions of the assistance-receivers. Gyimah-Brempong and Traynor (1999) argue that most low income countries like those in SSA, the political goal tends to override the goal of sustainable development. Governments of these countries strive to attract support from the majority of the population who are poor by trying to use the cheapest means of production in order to provide affordable products. So the financial sustainable development assistance received by these countries might be used to produce cheap output at whatever cost to the environment irrespective of the assistance's goal of sustainability in development.

A Model of Pre-Cure SDA

Pre-cure is hereby defined as "before putting any effort in environmental improvement or treatment". The financial assistance given to developing countries to finance activities that improve environmental quality before these countries take any action is therefore referred to as pre-cure assistance. When developing countries receive this financial assistance from rich countries, they can either finance environmental quality improvement activities, output growth activities or both. The financial SDA which is mostly provided as lump sum shifts the country's budget line to a higher level and establishes a new resource constraint. The assistance will therefore increase the country's budget thereby making higher environmental quality and output production affordable, giving higher optimal values of *Q* and *Y*.

Since developed countries are assumed to have indifference curves biased towards environmental quality such as U_{Dvpd}, illustrated in figure 1 (appendix 1), their expectations about the outcome of environmental air quality from the financial SDA, sometimes exceed the optimal of a poor country, that is, sometimes exceed $Q^{\bullet\bullet}$. In the absence of information asymmetry and rigidities in enforcement, SDA providers can monitor and control the use of the funds. In the event that their demands for environmental air quality exceed $Q^{\bullet\bullet}$ such as Q^{Dvpd}, with no enforcement rigidities and no information asymmetry, financial SDA can also be inefficient in developing countries (see figure 1 in appendix 1).
A high demand for environmental quality outcome by developed countries from SDA such as Q^{Dvpd} in figure 1 implies a movement by the developing country from the optimal SDA allocation, O_2, to a non-optimal point, O_{Dvpd}, with lower than optimal output, Y^{Dvpd}, but higher than optimal environmental quality, Q^{Dvpd}. This is however possible under perfect monitoring and perfect enforcement mechanisms, the necessary conditions that enable providers of financial SDA force developing countries to produce at their optimal consumption levels, which sometimes have higher environmental quality levels than the developing countries' own optimal as illustrated in figure 1.
Despite the creation of institutions to monitor the funds, perfect information is never achievable. The presence of moral hazard sometimes makes pre-cure SDA non-optimal in environmental management. Since developing countries prioritize output growth at the expense of environmental quality, in the absence of an effective monitoring system by the assistance providers, governments of these countries may give too much weight on output growth thereby producing more than optimal output and less than optimal environmental quality. For example, figure 1 indicates that if the government's utility, U_{Gvt}, is more biased towards output growth than the country's utility, U_1, then the country normally consumes

at a lower and inefficient indifference curve. Consider a situation where the government chooses allocation O_{Gvt} with larger than optimal output, Y^{Gvt}, and less than optimal environmental quality, Q^{Gvt}, to satisfy its own utility, U_{Gvt}, the country will consume at a lower and inefficient indifference curve, U_{Ineff}. Under extreme cases in which governments of developing countries derive insignificant utility from environmental air quality improvements, inefficient allocation might be further biased towards output growth to the extent that environmental quality might deteriorate to levels lower than the initial levels before the financial SDA. On the other hand, if developed countries have utility extremely biased towards high outcomes of environmental quality from financial SDA, then with perfect monitoring and no enforcement problems, output in developing countries might deteriorate to levels lower than those before financial SDA.

It is therefore indicated in this section that the inefficiency of financial SDA may be a result of either that the assistance providers, with perfect information and no enforcement problems, demand greater than optimal environmental quality outcomes from poor countries or that under moral hazard, governments of developing countries put greater than optimal weight on output production. Following this theoretical framework, the study assumes the presence of moral hazard and rigidities in enforcement by financial SDA providers. So the study assumes that the significant weight of inefficiency comes from the distortions caused by government allocations in developing countries.

Financial SDA in a Static Model with Clean-up Expenditure

The static model explains how economic activities are linked to the quality of the environment. It explains how economies divide income from production, *Y*, into consumption, *C*, and clean-up expenditures, *X*, and how waste from production and consumption affects the environment. This study attempts to fit in financial SDA in this theoretical model framework.

In this study, it is assumed that financial SDA is provided as a lump sum thereby adding to the total resources of a country to give its total income or output, $Y_{SDA} = Y + SDA$. Let the consumption after financial SDA be C_{SDA} and the country's clean-up expenditure after financial SDA be X_{SDA}, then by introducing financial SDA as lump sum, the developing country's national income expands from $Y = C + X$ to:

(3.2.1) $$Y_{SDA} = C_{SDA} + X_{SDA}$$

In this model, environmental quality is a function of national income, Y, and clean-up expenditures, X, that is, $Q = Q(Y, X)$. But with financial SDA the environmental quality will be a function of financial SDA-related national income and financial SDA-related clean-up expenditures, that is,

(3.2.2) $$Q = Q(Y_{SDA}, X_{SDA})$$

A total differentiation of (3.2.1) gives

(3.2.3) $$d\ Y_{SDA} = dC_{SDA} + dX_{SDA}$$ and that of (3.2.2) gives

(3.2.4) $$dQ = Q_{YSDA} dY_{SDA} + Q_{XSDA} dX_{SDA}$$

$$= Q_{YSDA}(dC_{SDA} + dX_{SDA}) + Q_{XSDA} dX_{SDA}$$ (from 3.2.3)

$$= Q_{YSDA} dC_{SDA} + (Q_{YSDA} + Q_{XSDA}) dX_{SDA}$$

where Q_{YSDA} is the change in environmental quality resulting from a marginal change in national income with financial SDA and Q_{XSDA} is the change in environmental quality resulting from a marginal change in financial SDA-related clean-up expenditures. Alternatively, Q_{YSDA} can be taken as the impact weight of a change in financial SDA-related consumption on environmental quality and $Q_{YSDA} + Q_{XSDA}$ is the impact weight of a change in financial SDA-related clean-up expenditures on environmental quality. It is expected that an increase in national output/income reduces environmental quality, that is, $Q_{YSDA} < 0$ and an increase in cleanup expenditures increases environmental quality, that is, $Q_{XSDA} > 0$. From (3.2.4), the term $Q_{YSDA} \; dC_{SDA}$ is negative, that is, $Q_{YSDA} \; dC_{SDA} < 0$, since $Q_{YSDA} < 0$ and $dC_{SDA} > 0$ and $dX_{SDA} > 0$. Therefore, a necessary but not sufficient condition for *dQ* to be positive is that $Q_{YSDA} < Q_{XSDA}$, that is, the environment must be more responsive to SDA-related clean-up processes than to SDA-related production waste accumulation, and the sufficient condition is $(Q_{YSDA} + Q_{XSDA}) dX_{SDA} > Q_{YSDA} dC_{SDA}$. The inequality illustrates that if financial SDA increases clean-up expenditures by more than the increase in consumption then environmental quality will improve, that is, in addition to the necessary condition, the conditions $dX_{SDA} > dC_{SDA}$ and $Q_{YSDA} + Q_{XSDA} > Q_{YSDA}$ improve *Q*. In other words, financial SDA improves environmental quality if clean-up expenditure is more responsive to national income changes than consumption.

If it is assumed that financial SDA enters the production process as financial capital input (the accounting capital definition), then the production function can be expressed as:

(3.2.5) $\quad Y = Y(K, L, T, SDA)$,

where *K*, *L*, *T and SDA* are physical capital, labour, technology and financial capital, respectively. A total differential of the production function gives:

(3.2.6) $\quad dY = Y_K dK + Y_L dL + Y_T dT + Y_{SDA} dSDA$, where $Y_Z = \frac{\partial Y}{\partial Z}$ for any Z. The environmental quality is a function of output, *Y*, and clean-up expenditures, *X,* that is,

(3.2.7) $\quad Q = Q(Y, X)$

Differentiating this function gives

(3.2.8) $\quad dQ = Q_Y dY + Q_X dX$

$$= Q_Y (Y_K dK + Y_L dL + Y_T dT + Y_{SDA} dSDA) + Q_X dX \quad \text{(from (3.2.6))}$$

$$= Q_Y Y_K dK + Q_Y Y_L dL + Q_Y Y_T dT + Q_Y Y_{SDA} dSDA + Q_X dX$$

Holding all other factors of production constant, we obtain the partial derivative of the environmental quality with respect to financial SDA as:

$$\frac{dQ}{dSDA} = Q_Y Y_{SDA} \quad (< 0), \text{ where } Q_Y = \frac{\partial Q}{\partial Y} \ (< 0) \text{ and } Y_{SDA} = \frac{\partial Y}{\partial SDA} \ (> 0)$$

So in cases where developing countries use financial SDA as financial capital input in production, the environmental quality might deteriorate due to increased output growth. In this case financial SDA reduces environmental quality.

THE EMPIRICAL MODEL

The study makes use of panel data econometrics to examine the efficacy of financial development assistance in managing CO_2 emissions in SSA countries. The choice of this method is based on the weight of its advantages relative to pure time series and pure cross-sectional data procedures. CO_2 emissions and Sustainable Development Assistance (SDA) vary across the SSA countries and also over time. Countries in the region exhibit individual-specific variables such as policies, managerial capabilities, corruption levels, among others and period-specific variables such as economic depressions and booms may not be ruled out. Such individual-specific and period-specific variables require the use of panel data. Pure cross-sectional data contain no information on period-specific variables or on the effect of period-specific variables and on the other hand, pure time series data contain no information on individual differences or on effects of individual-specific variables. Panel data make it possible to circumvent this problem while at the same time control for individual-specific and time specific heterogeneity.

Following the suggested theoretical relationship between SDA and greenhouse gases emissions, SDA and economic growth and the previous studies on the determinants of air quality by Shafik (1994), Grossman and Krueger (1994; 1995), and Seldom and Song (1992), this study considers two functional forms in SSA countries; the linear and the quadratic models. The cubic model in income provides an excellent fit for data related to developed countries (Seldom and Song, 1992). Hence it might not be an appropriate functional form for data related to less developed countries such as the SSA region.

The empirical model is derived from the theoretical framework in section 3 and it is defined as:

$$CO_2EMPGDP_{it} = f(SDAPGDP_{it}, ENUSEPGDP_{it}, MANSHARE_{it}, GDPPCAP_{it})$$

where $CO_2EMPGDP_{it}$ is the amount of carbon dioxide emissions embodied in a unit of GDP for country i in period t, $SDAPGDP_{it}$ is the amount of sustainable development assistance embodied in a unit of GDP for country i in period t, $ENUSEPGDP_{it}$ is a measure of the intensity of energy use per unit of output for country i in period t,

$MANSHARE_{it}$ is the share of manufacturing for country *i* in period *t* and $GDPPCAP_{it}$ is per capita income for country *i* in period *t* . The variables are in terms of per unit of output for easier comparisons across countries and over time. The GDP for every country in the study is expressed in US$ at 2000 constant prices. The variables abbreviations are defined in table below.

Definition of Variables

The dependent variable in this study, CO_2 emissions per unit of output (*CO_2EMPGDP*), gives the content of carbon dioxide embodied in a unit of output. This provides a proxy measure for environmental air quality. $CO_2EMPGDP_{it}$ is therefore the amount of carbon dioxide emissions per unit of output in country *i* in period *t* and is measured in metric tons of carbon. By using CO_2 emissions as the dependent variable makes it difficult to compare the state of the environmental quality across countries or over time. It is against this background that this study suggests to use *CO_2EMPGDP* as the dependent variable. *CO_2EMPGDP* makes it possible to compare whether the 1990 output was cleaner (embodied less emissions of CO_2) than the 2000 output in country *i* or whether country *i*'s output is cleaner (has less content of CO_2 emissions) than country *j's*. It is also easier to examine the impact of financial sustainable development assistance and energy use on the proportion of CO_2 embodied in output.

The main objective of this study is centred on the impact of financial SDA on environmental air quality in SSA countries. There are four explanatory variables in this study, namely, Sustainable Development Assistance per unit of output (*SDAPGDP*), energy use per unit of output (*ENUSEPGDP*), manufacturing share or the percentage value added by manufacturing (*MANSHARE*), the Gross Domestic Product per capita (*GDPPCAP*) and four pre-determined variables, the lagged variables of *SDAPGDP,* $SDAPGDP_{i,t-1}$ and $SDAPGDP_{i,t-2}$ and the lagged variables of *GDPPCAP*, $GDPPCAP_{i,t-1}$ and $GDPPCAP_{i,t-2}$.

The lagged variables of SDA are included as possible determinants of the variations in environmental quality. When developing countries receive the assistance, they do not instantaneously use the funds but they require planning time for investment decisions. Even if the SDA is instantaneously invested, time lag between the investment period and output production always exists. The existence of such time lags implies that the decisions that were made during the previous periods might have an impact on the current outcomes. SDA received in the previous periods might have a strong influence on current emissions. However, it is not easy to pick the actual memory length for a variable. The SDA might have a 10-year memory which calls for several lagged variables but this study assumes that SDA has a 2-year memory history. In the case of previous period's incomes, the study proposes to include income lags as possible determinants of air quality since high incomes in the previous period might add up to current clean-up budget or there might be a period lag between output production and conversion into green house gases. An example might be explained by the importation of automobiles in poor countries, characterized by a time lag between the realization of increased income and the increased acquisition of automobiles, which normally takes long because of importation and clearance procedures.

$SDAPGDP_{it}$ is the amount of SDA embodied in every unit of output produced in country *i* in period *t* and is measured in constant 2000 US$ for all countries in the study. The use of per unit output SDA deflates the inflated values of SDA thereby making it possible to compare variations of SDA across SSA countries. $ENUSEPGDP_{it}$ measures how much energy is used per every unit of output in country *i* in period *t*. It is measured in terms of kilograms of oil equivalent. The other variables, *GDPPCAP* and *MANSHARE* are per capita income and manufacturing share respectively. Manufacturing processes such as cement production, coal production, and oil refinery are some of the largest emitters of carbon dioxide. Manufacturing in turn plays a major role in the size of a country's GDP, increased manufacturing output increases the overall output of a country. It is against this background that the two variables are both considered to be important determinants of variations in environmental air quality. *GDPPCAP* is measured at 2000 constant prices in US$ for every country in the study for comparability reasons. In the dynamic model, $CO_2EMPGDP$ is assumed to have memory of its own history, that is, it memorizes its previous period values. $CO_2EMPGDP_{i,t-1}$ influences the current size of emissions because a proportion of the current clean-up expenditure has to be used to clean-up the previous period emissions.

It is also assumed that there is a time lag between the time Sustainable Development Assistance (SDA) is received and the desired outcomes. This study considers the effect of SDA received in the previous two years on the current CO_2 gases emissions. In addition, the lagged variables of income are also considered since previous income levels might have an impact on the nation's budget for current clean-up expenditures, its current fleet of automobiles (carbon emitters), and its current state of technology . The model ($CO_2EMPGDP_{it} = f(SDAPGDP_{it}, ENUSEPGDP_{it}, MANSHARE_{it}, GDPPCAP_{it})$) will therefore include the two lagged variables of $SDAPGDP$ and those of $GDPPCAP$. Hence it is expressed as:

$CO_2EMPGDP_{it} = \eta_i^{\bullet} + Z_{it}\beta + \varepsilon_{it}$, where Z_{it} is a $1 \times K$ row vector of all the explanatory and pre-determined variables, that is, Z_{it} contains $SDAPGDP_{it}$, $ENUSEPGDP_{it}$, $MANSHARE_{it}$, $GDPPCAP_{it}$, $SDAPGDP_{i,t-1}$, $SDAPGDP_{i,t-2}$, $GDPPCAP_{i,t-1}$, and $GDPPCAP_{i,t-2}$. All the variables in Z_{it} are assumed to be exogenous in this model. ε_{it} is the random error term that satisfies, $\varepsilon_{it} \sim IID\ (0,\ \sigma^2\ )$. Both Z_{it} and ε_{it} are assumed to be independently distributed for all *i* and *t*. $\beta = [\beta_1,.....,\beta_K]'$ is the $K \times 1$ column vector of slope coefficients and $\eta_i^\bullet$ is a constant specific to individual *i*. Despite the fact that some of the countries in SSA region like Mozambique and Angola have been in civil wars in the 1980s, they continued to receive sustainable development assistance. The WBDIS of 2007 indicates that every country in the SSA region received SDA at least once between 1970 and 2000 irrespective of its policy rating, corruption level and other issues such as political stability. In addition to this, the World Bank (2001) reports that lack of determinants for the size of sustainable development assistance to be provided to a given developing country by developed countries might cause the assistance to be ineffective. The absence of conditionality placed on SDA by donors provides an insight of ruling out the presence of a reverse causality or simultaneity bias between CO_2 emissions and financial SDA in SSA region from 1970 to 2000.

The study also considers a situation in which the previous period CO_2 emissions influence the current period emissions. It is assumed that the accumulation of previous emissions in the current period might increase the current emissions due to the deprivation of the current clean-up expenditure of its income share, which will be allotted to previous emissions clean-up. In this case a dynamic panel data model is considered. The model, which includes the lagged variable of the dependent variable, $CO_2EMPGDP_{i,t-1}$, is as follows:

$CO_2EMPGDP_{it} = \eta_i^\bullet + CO_2EMPGDP_{i,t-1}\lambda + Z_{it}\beta + \varepsilon_{it}$. λ is the autoregressive coefficient assumed to be less than one in absolute value, a standard assumption for stationary AR(1) models in pure time series. Applying Ordinary Least Squares (OLS) on the model gives biased and inconsistent estimators since ε_{it} is correlated with $CO_2EMPGDP_{i,t-1}$. The within-individual estimator of the autoregressive coefficient in this model is inconsistent, with negative bias, if N→∞ and T is finite. It is only consistent if T→∞ for any N. The estimators of the N intercepts $\eta_i^\bullet$ are inconsistent if N→∞ and T is finite. They are consistent if T→∞ for any N.

To eliminate the fixed individual-specific effects and to be assured of consistent estimators, the study estimates the model in differenced form by instrumental variables. The lagged levels, $CO_2EMPGDP_{i,t-2}$ and $CO_2EMPGDP_{i,t-3}$, the Z_{it} variables and the lagged differences $\Delta CO_2EMPGDP_{i,t-2}$ and $\Delta CO_2EMPGDP_{i,t-3}$ are potential instruments for $\Delta CO_2EMPGDP_{i,t-1}$ in the following model:

$$\Delta CO_2EMPGDP_{it} = \Delta CO_2EMPGDP_{i,t-1}\lambda + \Delta\varepsilon_{it}$$

These potential instruments are correlated with $\Delta CO_2 EMPGDP_{i,t-1}$ and uncorrelated with $\Delta\varepsilon_{it}$. This study uses all of these stated potential instruments except $\Delta CO_2 EMPGDP_{i,t-2}$ which is dropped because of perfect multicollenearity. A detailed discussion on dynamic panel data models can be found in Biørn (2007), Baltagi (2005), Hsiao (2003), and Greene (2003), among others.

Following the Hausman test, the results confirm that the random effects model is more appropriate than the fixed effects model in modelling the impact of financial SDA on CO_2 emissions in SSA countries. Detailed discussions on the Hausman test are found in Hausman (1978), Biørn (2007), Baltagi (2005), Hsiao (2003), and Greene (2000), among others.

The Random Effects Model

In models with fixed effects, no assumptions are made about individual-specific intercepts, $\eta_1^{\bullet}, \eta_2^{\bullet}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots, \eta_N^{\bullet}$. In the case that the individual-specific effects are randomly distributed across units, a random effects model will be more appropriate. The regression equation is given by:

$$CO_2 EMPGDP_{it} = \eta_i^{\bullet} + Z_{it}\beta + \varepsilon_{it}$$

This equation is defined over i = 1,........, N and t = 1, ..., T. The individual-specific intercepts, $\eta_i^{\bullet}$, satisfy E($\eta_i^{\bullet}$) = k, var($\eta_i^{\bullet}$) = σ_η^2, cov($\eta_i^{\bullet}, \eta_j^{\bullet}$) = 0 for $j \neq i$ and $i, j = 1, \ldots\ldots\ldots\ldots, T$, where k and σ_η^2 are unknown constants. It is also assumed that $\eta_i^{\bullet}$, ε_{it} and all the explanatory variables are independently distributed. By letting $\eta_i = \eta_i^{\bullet} - E(\eta_i^{\bullet}) = \eta_i^{\bullet} - k$, we can express the regression equation with stochastic individual-specific effects as:

$$\begin{aligned} GHGEMPGDP_{it} &= \eta_i^{\bullet} + Z_{it}\beta + \varepsilon_{it} \\ &= k + Z_{it}\beta + \varepsilon_{it} + \eta_i \\ &= k + Z_{it}\beta + u_{it} \end{aligned}$$

Where $u_{it} = \varepsilon_{it} + \eta_i$

$$\varepsilon_{it} \sim IID(0_{T,1}, \sigma_\varepsilon^2 I_T),\ i = 1,\ldots\ldots\ldots, N \quad t = 1, \ldots\ldots\ldots\ldots, T$$

$$\eta_i \sim IID(0, \sigma_\eta^2)$$

u_{it} is a composite or gross disturbance composed of two different error components, hence regression models of this type are also referred to as error components models. The GLS gives MVLUE estimators if σ_η^2 and σ^2 are known. In the event that the two variances are not known, the FGLS gives MVLUE estimators. The two estimators have an advantage of being weighted averages of the within-group and between-group estimators and therefore enable the researcher to extract information from the two variations as discussed in Green (2003) and Owusu-Gyapong (1986).

RESULTS

The Random Effects Results (Linear Form)

Following the Hausman results, the study applies the random effects model. The random effects results from a linear model illustrated in Table 1 (appendix 2) provide no evidence of a statistical significant impact of financial SDA and its lagged values on variations in CO_2 emissions in SSA. The result compares well with the theory of utility maximization discussed in section 3, which assumes that poor countries' indifference curves are biased towards output growth, implying that a lump sum increase in the country's budget is likely to be followed by an over-weighed output growth and an under-weighed environmental quality improvement; an explicit support to the study hypothesis that SDA weakly reduces CO_2 emissions in poor countries. Based on the statistical evidence presented in the table below, the study's hypothesis of a weak negative relationship between $CO_2EMPGDP$ and *SDAPGDP* cannot be rejected.

CO_2 emissions in SSA countries are significantly and positively influenced by energy use. The results in table 1 indicate that a one unit increase in energy use increases the share of CO_2 emissions embodied in a unit of output by about 0.04262%. This effect is very large given the almost constant average carbon emissions in SSA countries. The result is expected especially in poor countries like SSA countries in which technological growth is very slow leading to low rates of energy source substitution. But in countries where technology replaces highly pollutant energy sources by less pollutant ones, the coefficient of energy use might take either sign, positive or negative.

The Gross Domestic Product per capita and the share of manufacturing are found to be statistically significant determinants of CO_2 emissions in SSA countries. Increases in both per capita GDP and manufacturing share will increase CO_2 emissions in SSA countries. The coefficients of *GDPPCAP* and *MANSHARE* are both statistically significant at 5% level. This result agrees with Shafik (1994) and Grossman and Krueger (1995). In SSA region, no country exceeds per capita real income of US$10 000, therefore this study's findings do not deviate from Grossman and Krueger's in terms of the current income variable. However, in terms of the lagged income variables, the study findings deviate from Grossman and Krueger's who found evidence of a significant impact of these lagged variables on environmental quality.

Dynamics of the Model

Despite the existence of a positive relationship between changes in historic emissions and current emissions, the study finds no statistical evidence to reject the hypothesis that the coefficient of $\Delta CO_2 EMPGDP_{i,t-1}$ in the dynamic model is zero. So we find evidence that historical growth rates of $CO_2EMPGDP$ have insignificant impact on current growth of CO_2 emissions in SSA region.

The Quadratic Functional Form

Table 2 in appendix 2 provides the results of the quadratic functional form in terms of the SDA variable. The weak explanatory power of the income variable in the quadratic model might be a result of the low levels of per capita incomes in SSA countries as evidenced by Shafik (1994), Grossman and Krueger (1995). So given the maximum per capita income of less than US$8000 in SSA countries, quadratic and cubic income terms are expected to be statistically insignificant. Despite the negative sign of the squared income coefficient which implies an inverted "U" shaped curve for the relationship between CO_2 emissions and per capita income, the results provide no evidence to support the quadratic functional form in income variable.

In terms of the sustainable development assistance, the quadratic functional form seems to provide the best fit. The variables which are statistically significant in the linear random effects model presented in section 5.1 are still statistically significant at the 5% level in the quadratic form. In addition, the coefficient of the squared term of sustainable development assistance, $SDAPGDP_{it}^2$, is also statistically significant at the 5% level and most importantly, the chi-square test for joint significance of the coefficients of the quadratic model provide evidence that the coefficients are simultaneously different from zero. The chi-square test statistic is 43.24 and is statistically significant at the 1% level, implying that the null hypothesis that the coefficients of the quadratic model are jointly equal to zero is rejected.

The coefficient of the squared term, $SDAPGDP_{it}^2$ (the quadratic term) is 0.0019917 (> 0), an indication that the relationship between SDA and CO_2 emissions can be illustrated through a "U" shaped curve in SSA countries. The quadratic function in terms of SDA can be presented as:

$CO_2EMPGDP_{it} = 0.0000225 - 0.0013473 SDAPGDP_{it} + 0.0019917 SDAPGDP_{it}^2 + G_{it}^{/}\theta$ where G_{it} is a vector of all the other variables in the quadratic model in table 2 and θ is a vector of the associated coefficients. By partial differentiation of this function with respect to $SDAPGDP_{it}$ and equating the derivative to zero, we get the turning point as 0.338. This value means that in SSA region CO_2 emissions decrease with increases in SDA embodied in a unit of output when SDAPGDP is below US$0.338 per US$1 of output. Thereafter, CO_2 emissions increase with increase in SDA. The turning point is within the study data range but is far above individual countries' averages and yearly averages in SSA region.

CONCLUSIONS AND RECOMMENDATIONS

Summary of the Study

The study empirically investigated the impact of financial SDA, per capita income, manufacturing share and energy use on CO_2 emissions in SSA countries. The main objective was to find out whether sustainable development assistance reduces carbon emissions or increases these emissions in SSA countries. The random effects estimation procedure (in linear form) finds no statistical evidence that in SSA region SDA linearly reduces CO_2 emissions although its coefficient has the expected negative sign. In the quadratic functional form in terms of SDA variable, the coefficients are jointly significant at the 1% level, implying that the impact of SDA on environmental air quality depends on the size of the SDA a country receives. The study finds evidence that before the turning point explained in section 5, increases in SDA reduce CO_2 emissions in SSA countries and thereafter, increases in SDA increase emissions. Therefore, the study finds no evidence that CO_2 emissions in SSA countries linearly decrease with increases in SDA and its lags. In the assumed dynamics, the dynamic random effects estimation procedure finds no evidence of a significant impact of previous period CO_2 emissions on current emissions despite the existence of a priori expected positive sign of the autoregressive coefficient.

The random effects results provide evidence that Gross Domestic Product per capita, manufacturing share and energy use are significant determinants of carbon dioxide emissions in SSA countries. In the linear model of section 5.1, per capita income variable is significant at the 5% level while the study finds no evidence of a significant impact of the lagged variables of per capita income on CO_2 emissions in SSA. Energy use is significant at the 1% level whereas manufacturing share is significant at the 5% level. These variables are also significant in the quadratic model of section 5.3. The study findings provide no evidence to reject the main hypothesis of the study that SDA weakly reduces CO_2 emissions in poor countries. Both the linear and quadratic functional forms provide evidence that environmental air quality in SSA deteriorates steadily with increases in per capita income, energy use and manufacturing share.

The study is limited to a sample of SSA countries instead of the preferred population because of missing data for some countries. Although the study is restricted to a sample of 28 SSA countries because of data unavailability, the sample contains more than 60% of the SSA countries, making it large enough to be a reliable representative of the region. The major limitation of the study pertains to the non-inclusion of variables which are thought to be important causes of the ineffectiveness of SDA in poor countries, variables such as political instability, corruption levels, research expenditure and technological growth. These variables could not be included in the study because of the unavailability of the time series data. Hence the study is only limited to explaining whether SDA improves environmental quality in SSA or worsens it and not to explaining the causes of the ineffectiveness of SDA in improving environmental quality in SSA.

Policy Recommendations

The findings provide an insight into how financial SDA influences CO_2 emissions in SSA countries. In view of these findings, it is evidenced that increases in financial SDA improves environmental quality in those SSA countries with average SDAPGDP below US$0.338 in a US$1 unit of output. The researchers therefore recommends that developed countries should continue with their policy of financing sustainable development in these countries since most of these countries' average SDAPGDP is far below the turning point of US$0.338. In particular, the study recommends financial sustainable development assistance to be directed towards those countries with average SDAPGDP below the turning point, that is, the provision of SDA should depend on the receiving country's current size of assistance.

A Suggested Model of Environmental Financing: Incentive-based Financing

The incentive-based or post-cure environmental financing model stipulates that financial assistance given to developing countries for environmental quality improvements achieves its objective if supplied as a function of the effort contributed by the receiving country in environmental quality improvements. The greater is the proportion of the financial assistance in covering the contribution costs the greater is the effort applied in environmental quality improvements by these countries. We derive this model from the Marshallian productivity theory which states that the labour supplier applies more effort when he knows that all the benefits from the marginal unit of effort is accrued to himself than when he receives only partial benefits of the marginal unit of effort. In other words the Marshallian model which assumes the presence of prohibitive monitoring costs by the assistance providers would predict financial sustainable development assistance supplied with $\lambda = 1$ to be more efficient than the one supplied with $\lambda < 1$. Despite its attractive flavor, the post-cure environmental financial assistance model is not yet common in the field of environmental financing although some efforts are being made towards applying it, for example, the UN's Carbon Finance for Sustainable Energy in Africa (CFSEA) initiative.

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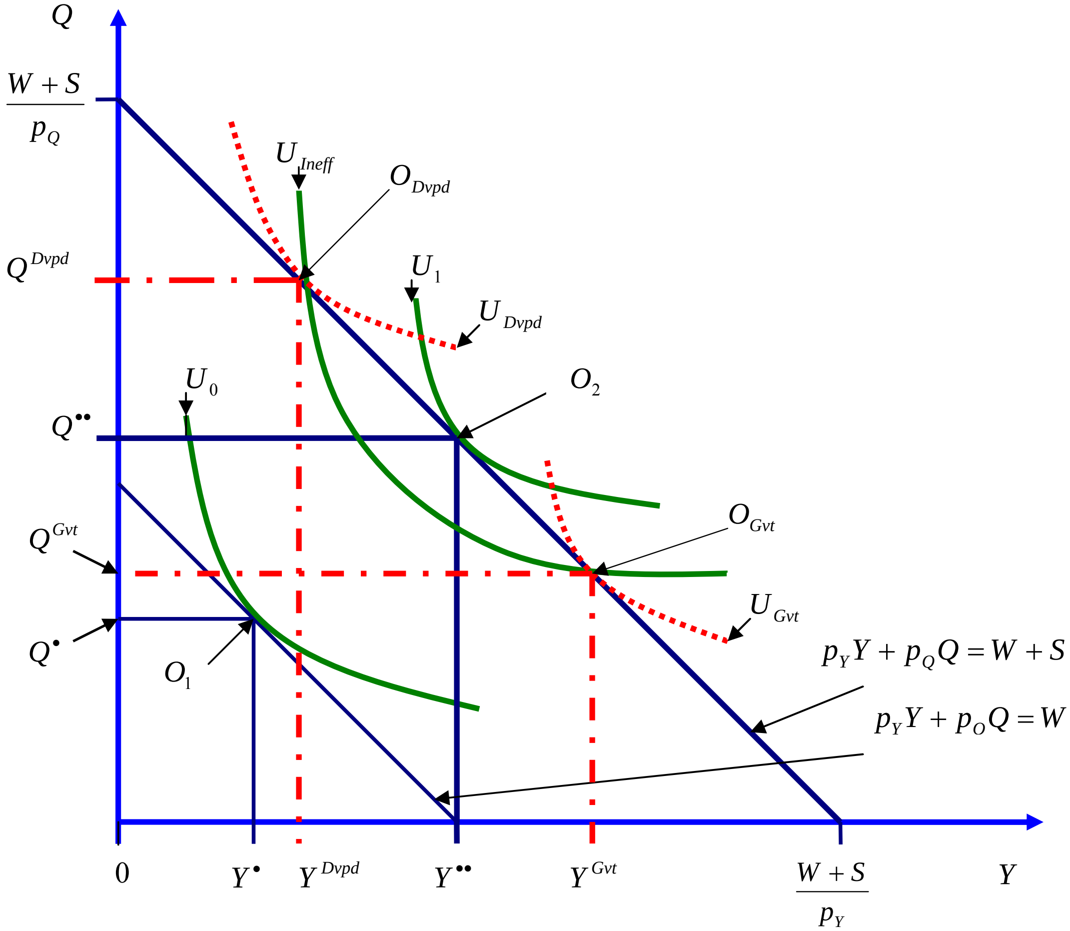
ABOUT AUTHORS

Carren Pindiriri: Lecturer, Department of Economics, University of Zimbabwe, Zimbabwe.

Clainos Chidoko: Lecturer, Department of Economics, Great Zimbabwe University, Zimbabwe.

Appendix 1
Figure 1



In the absence of information asymmetry and rigidities in enforcement, high demands for environmental quality by SDA providers may sometimes render the assistance inefficient in developing countries. On the other hand, in the presence of moral hazard, governments of poor countries may put too much weight on output growth rendering the assistance inefficient as well.

Appendix 2

Table 1

The random effects coefficients (linear model)

$CO_2EMPGDP_{it}$	Coef.	Std. Err.	z	P> z
$SDAPGDP_{it}$	-0.0000223	0.000545	-0.04	0.967
$ENUSEPGDP_{it}$	0.0004262	0.000088	4.84	0.000***
$GDPPCAP_{it}$	0.0360	0.0150	2.40	0.017**
$MANSHARE_{it}$	0.002817	0.001095	2.57	0.010**
$SDAPGDP_{i,t-1}$	-0.000168	0.000656	-0.26	0.798
$SDAPGDP_{i,t-2}$	-0.000175	0.000534	-0.33	0.742
$GDPPCAP_{i,t-1}$	0.364	1.73	0.21	0.833
$GDPPCAP_{i,t-2}$	0.584	1.21	0.48	0.630
CONSTANT	-3.70	185	-0.02	0.987

***means statistically significant at the 1% level
**means statistically significant at the 5% level
*means statistically significant at the 10% level

Table 2

The random effects coefficients (quadratic model in SDA and GDP)

$CO_2EMPGDP$	Coef.	Std. Err.	z	P> z
$SDAPGDP_{it}$	-.0013473	.0010875	-1.24	0.215
$ENUSEPGDP_{it}$	.0003998	.0000976	4.10	0.000***
$GDPPCAP_{it}$	0.0743	0.0288	2.58	0.010**
$MANSHARE_{it}$	.002953	.0011067	2.67	0.008***
$SDAPGDP_{i,t-1}$	-.0004833	.0013659	-0.35	0.723
$SDAPGDP_{i,t-2}$	-.0000507	.0010989	-0.05	0.963
$GDPPCAP_{i,t-1}$	0.0000035	0.0000307	0.11	0.909
$GDPPCAP_{i,t-2}$	-0.000205	0.000232	-0.88	0.376
$SDAPGDP_{it}^2$	.0019917	.001012	1.97	0.049**
$GDPPCAP_{it}^2$	-0.000647	0.000421	-1.54	0.124
CONSTANT	.0000225	.0002859	0.08	0.937

***means statistically significant at the 1% level
**means statistically significant at the 5% level
*means statistically significant at the 10% level

$\chi^2(11) = 43.24$ Prob > $\chi^2 = 0.0000$