Impact of Global Warming on Rural-Urban Migration and Net Emigration in Forefront Sub-Saharan Countries

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ABSTRACT

Global warming has recently raised a lot of concerns about the future of our planet in terms of inhabitability. These concerns focus particularly on the possible increase in the migration toward more hospitable urban areas within a country or toward more hospitable countries. However, to our knowledge, there is no quantitative study to assess the impact of global warming on migration in Sub-Saharan Africa. Therefore, this paper attempts to determine whether global warming increases rural-urban migration and net emigration (i.e. emigration of nationals out of a country minus immigration of foreigners into the country) over the period 2000-2005 in six forefront Sub-Saharan countries, namely Burkina Faso, Chad, Mali, Mauritania, Niger and Senegal. We found that global warming alone is insignificantly related to rural-urban migration and net emigration. However, when associated with other independent variables or cofactors such as population growth rate and gross domestic product growth rate, global warming increases both rural-urban migration and net emigration.

INTRODUCTION

Global warming is the gradual increase in the earth's surface temperature. While rural-urban migration is the displacement of nationals from rural places of residence to urban places of residence in the same country, and net emigration the emigration of nationals out of a country minus immigration of foreigners into the country. Global warming has recently raised a lot of concerns about the future of our planet in terms of inhabitability (Intergovernmental Panel of Climate Change (IPCC), 2007; Stern, 2007; United Nations Framework Convention on Climate Change (UNFCCC), 2007; *The Sunday Times*, May 27, 2007; Gore, 2006; Faure *et al.*, 2003;

Kyoto Protocol, 1997). These concerns focus particularly on the possible increase in the migration toward more hospitable urban areas within a country or toward more hospitable countries (Darrel *et al.*, 2004; Zolberg and Benda, 2001). However, to our knowledge, there is no quantitative study to assess the impact of global warming on migration in Sub-Saharan Africa. Therefore, this paper attempts to determine whether global warming increases rural-urban migration and net emigration over the period 2000-2005 in six forefront Sub-Saharan countries, namely Burkina Faso, Chad, Mali, Mauritania, Niger and Senegal.

In the first part of the paper, we review the literature. In the second and third parts, we present the methodology and the results respectively. This is followed by a discussion in the fourth part and the conclusion with some policy implications in the fifth part.

REVIEW OF THE LITERATURE

The temperature near the surface of the earth is determined by the balance between solar radiation energy and heat reflected from earth to outer space. Sunlight warms the surface of the earth, which then cools down when the heat (infrared rays) is released from it. However, there are heat-absorbing atmospheric gases which absorb a certain percentage of heat (infrared rays) reflected from the surface of the earth. The atmosphere, thus warmed, radiates infrared rays out toward space and back toward the surface of the earth, warming the latter. In this manner, the earth surface temperature is kept at around 15°C in average, realizing an environment suited for the existence of humans, animals, plants and other life forms (Osaka Prefectural Government, 2007; IPCC, 2007). See Figure 1.

Figure 1 Mechanism of Greenhouse Effect
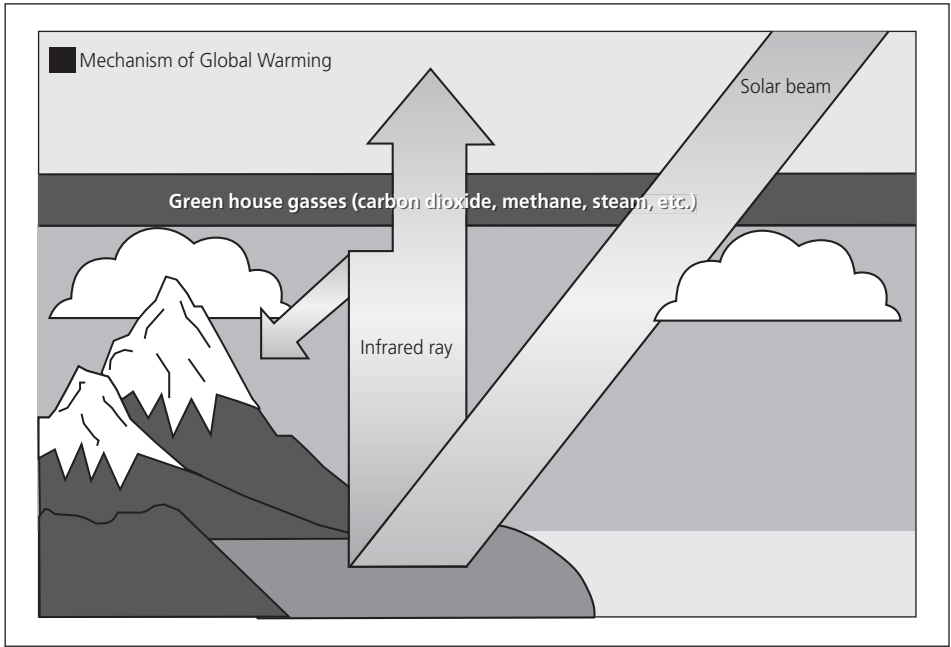
Source Osaka Prefectural Government (2007).

This natural process of heating the surface of the earth by the sunlight is called the 'greenhouse effect,' and the infrared-absorbing gases in the atmosphere are called 'greenhouse gases.' If not for greenhouse gases, the temperature of the earth would drop by over 30°C to about –18°C (Osaka Prefectural Government, 2007; IPCC, 2007; Gore, 2006). To understand this mechanism, let us take the example of a desert. During the day it can be hot as Hades, but at night it can be extremely cold. The variation of the temperature is due to a lack of temperature regulators. During the day, there is nothing to regulate the heat such as water. When night falls, there is nothing that stores the heat of the day.

Greenhouse gases are composed of carbon dioxide (63.7%), methane (19.2%), chlorofluorocarbon (CFC (10.29%)), nitrogen suboxide (5.7%) and others including steam (1.2%) (Osaka Prefectural Government, 2007). See Figure 2.

Figure 2 Atmospheric Concentration of Carbon Dioxide and Contribution of Greenhouse Gases to Global Warming
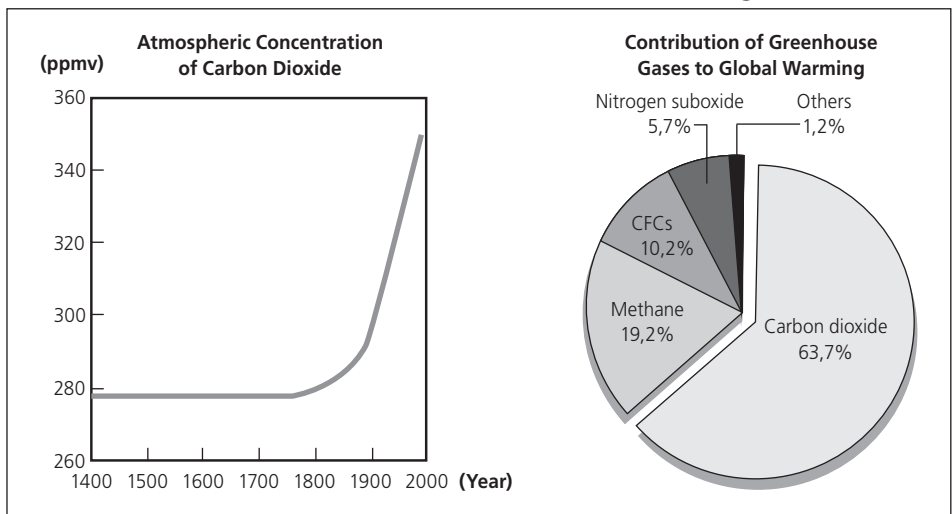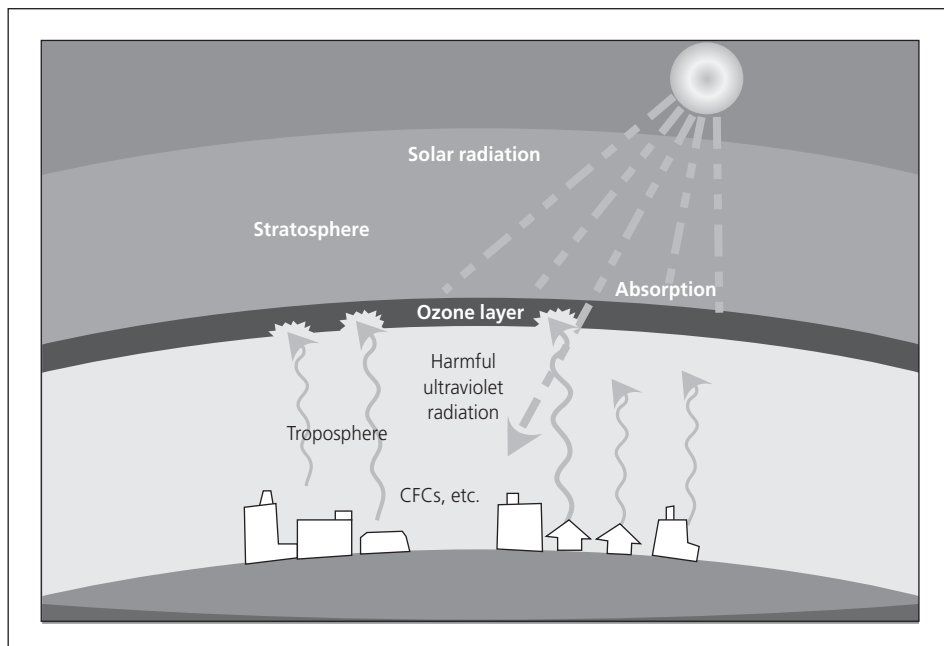

Source Osaka Prefectural Government (2007)

In 1994, worldwide carbon dioxide emissions amounted to about 6.2 billion tons carbon equivalent (i.e. the stock of greenhouse gases in the atmosphere which is equivalent to 430 ppm CO_2 or CO_2e). Where ppmv is a unit for ratio of volume in parts per million. The ranking of selected countries, Africa and South America in emission percentages is as follows: USA (22.4%), China (13.4%), Russia (7.1%), Japan (4.9%), India (3.8%), Germany (3.5%), Africa (3.4%), South America (3.1%), France (3%), UK (2.4%), Canada (2%), Italy (1.7%), Oceania (1.4%) and others (27.9%). It appears that less developed countries in Africa and South America produced fewer volume of carbon dioxide as compared to developed countries. The concentrations of carbon dioxide have already caused the world to warm by more than a 0.5°C and will lead to at least a further 0.5°C warming over the next few decades, because of the inertia in the climate system (Osaka Prefectural Government, 2007; Stern, 2007).

The carbon dioxide has been increasing remarkably, mostly as a result of the combustion of fossil fuels such as coal, petroleum and natural gas. Methane forms naturally in swamps, lakes and marches, and is also generated as a result of human activities such as livestock

farming, paddy field cultivation and underground disposal of waste materials. CFCs are artificial gases that did not exist in nature before the Industrial Revolution 200 years ago. They have been in wide use as coolant gases in air conditioners and refrigerators, and as industrial cleansing agents. In recent years, CFCs have come to be known as an ozone layer destroyer. Nitrogen suboxide is a byproduct of the combustion of organic substances and nitrogen fertilizers (IPCC, 2007; Stern, 2007; Osaka Prefectural Government, 2007). See

**Figure 3** Destruction of ozone layer by CFCs

Figure 3.

The ozone layer, situated in the stratosphere about 15 to 30 km above the earth's surface, plays the important role of 'space suit' that protects the living beings by absorbing harmful ultraviolet radiation from the sun.

The mechanism of ozone layer destruction by CFCs is as follows. Since CFCs are chemically stable, when released into the atmosphere they pass through the troposphere at about 20 km altitude without decomposing, reaching the stratosphere, where they are chemically decomposed by short-wavelength ultraviolet rays, releasing chlorine atoms. See Figure 4. In a chain reaction, the chlorine atoms destroy the ozone layer in the stratosphere. This destruction of the ozone layer increases the amount of harmful ultraviolet radiation, which in turn can result in increased cases of skin cancer, and visual impediments such as cataract. It can also hinder the growth of plants and negatively impact small living organisms, such as zooplankton, shrimp larvae and the young fish.

Beside the destruction of the ozone layer by CFCs, as we have seen, the earth is kept warm by greenhouse gases in the atmosphere. Thus, global warming would exist to a certain extent if man did not exist on Planet Earth. However, since the Industrial Revolution, man has

**Figure 4** Mechanism of Ozone Layer Destruction by CFC in Stratosphere
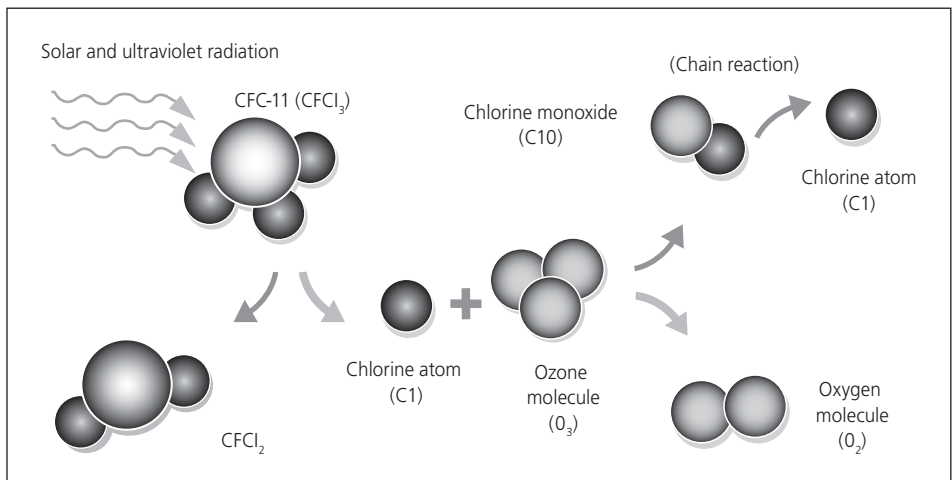
contributed to the greenhouse gases released into the earth's atmosphere. These combine with nature's own greenhouse gases has upset the natural balance, increasing the volume of greenhouse gases which resulted in global warming. Scientists believe that the current trend in global warming could soon result in the warmest temperatures for over 10 000 years. If alternative methods of generating energy are not realized, global temperatures could rise by as much as 5°C over the next century. Such a rise would have devastating consequences. Extreme weather conditions such as droughts, unexpected snow in some areas, and flooding would become commonplace (IPCC, 2007; Stern, 2007). Therefore, the current debate on global warming is not about its existence, but about what is due to nature and what is due to man or manmade.

On the one hand, those who believe that the increase in global warming is manmade (e.g. IPCC, 2007; Stern, 2007; Osaka Prefectural Government, 2007; Worldwatch Institute, 2007; Linden, 2007; Gore, 2006; Kolbert, 2006; Arctic Climate Impact Assessment, 2005; Henson, 2006; Weart, 2004; Raynaud, 2000; Dow and Downing, 2001) argued that the volume of greenhouse gases has markedly increased since the Industrial Revolution. According to them, the atmospheric concentration of carbon dioxide, which was about 280 ppmv before the Industrial Revolution, has reached 365 ppmv, i.e. about 1.3 times in 1994. Moreover, as we have seen, less developed countries emitted a fewer volume of carbon dioxide than developed countries. However, it turns out that they are those who suffer the most for the consequences of global warming due to the increase in the volume of carbon dioxide because they are less equipped to protect themselves against the devastating consequences of global warming (IPCC, 2007; Stern, 2007). The atmospheric concentration of methane also increased from about 700 ppbv (ppbv is a unit for ratio of volume in parts per billion) before the Industrial Revolution to some 1 600 ppbv, i.e. about 2.3 times in 1994, as human activities have expanded. CFCs which did not exist before the Industrial Revolution has expanded. Finally, the atmospheric concentration of nitrogen suboxide, about 275 ppbv before the Industrial Revolution, had increased to 312 ppbv by 1994, i.e. about 1.1 times. It should be noticed that CFCs production is now banned internationally.

On the other hand, those who think that the increase in global warming is mainly due to nature can be divided into two groups. Those who believe that the increase in global warming is mainly due to solar activity related to solar cycle and those who think that it is difficult to forecast the consequences of global warming. The first group (e.g. Svensmark, 2007; Benestad, 2006; Leroux, 2005; Soon and Yaskell, 2004; Hoyt and Schatten, 1997) challenged the accepted wisdom of the scientific community and argued that solar radiations activity or sub-atomic particles from exploded stars have more effect on climate than manmade CO_2 or carbon dioxide. While the second group (e.g. Lomborg, 2007, 2001; Avery and Singer, 2007; Michaels, 2005, 2004; Mathiesen, 2004; Philander, 2000) argued that environmentalists, politicians and media sensationalists, those who hate capitalism and like big government, are exaggerating the impact of global warming in order to manipulate the public to advance their own agenda. This group points out that according to the scare tactics of environmentalists, politicians and media sensationalists, no matter how much we sacrifice there would still be more to do.

However, what is not disputed among debators is the existence of the increase in global warming. Moreover, the consensus among the majority of scientists which is reflected in the reports of the UN international panel of scientists is that a great part of the increase in global warming is manmade (IPCC, 2007; Raynaud *et al.*, 2000; Petit *et al.*, 1999). See Figure 5.

Figure 5 4 cycles of glaciation
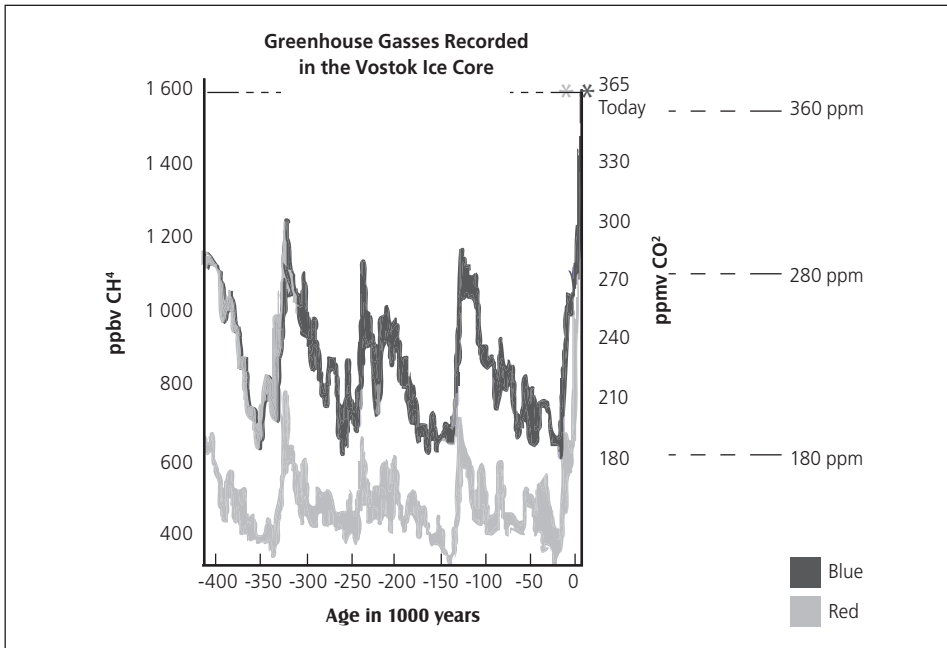
Source Raynaud *et al.* (2000).

On the horizontal axis, – 400 stands for – 400 000 years while 0 stands for the beginning of the present time. The blue graph represents the evolution of the concentration of carbon dioxide (CO_2) for the past 400 000 years. Whereas the red graph represents the evolution

of the concentration of methane (CH_4) for the past 400 000 years. On the two graphs each trough corresponds to a glaciation. Over the 400 000 years, we had 4 glaciations. The last glaciation occured about 20 000 years ago.

It should be noticed that between two consecutive glaciations or interglaciation period the carbon dioxide and methane levels respectively rise to the levels which are approximately those we had in 1 800 (280 ppm ; 700 ppbv), i.e . before the Industrial Revolution. Whereas now the level of carbon dioxide is about 365 ppm and that of methane about 1 600 ppbv. This shows, according to Raynaud *et al.* (2000), that we are far above the levels reached during the previous 3 interglaciation periods.

It is argued and predicted that the increase in global warming results and will result in a more increase in rural-urban migration, net emigration and the number of global refugees (Worldwatch Institute, 2007; Martin *et al.*, 2006; Unruh *et al.*, 2005; Houghton, 2004; O'Neill *et al.*, 2001; Zolberg and Benda, 2001). Moreover, because of the melting down of glaciers and the dilatation of sea water due to global warming, it is reported that the pacific Island of Tuvalu has signed an agreement with New Zealand to move its population to New Zealand in the event of serious climate change impacts, that a fifth of Bengladesh population could be under water with a 1m rise in sea levels, and that Banjul the capital of Gambia will be submerged by water (Stern, 2007).

Although, there has been a number of studies on migration and desertification in Sub-Saharan Africa related to global warming (Thornton *et al.*, 2006; Brooks, 2004; Gado, 1998; Chouiki, 1997; Traoré, 1997; Diop-Maes, 1997; Oucho, 1995; Diallo, O., A. Diouf *et al.*, 1991; Justice *et al.*, 1991; Tucker, 1991; Ayiemba, 1990; Diallo, 1981) as well as unexpected snow in Johannesburg (South Africa) and an unusual flooding during an extended raining season in forefront Sub-Saharan countries in 2007, it emerges from this literature review that no quantitative study has been done to determine whether global warming increases rural-urban migration and net emigration in forefront Sub-Saharan countries. This paper attempts to fill this gap in the literature. Now let us turn to the methodology.

METHODOLOGY

The methodology consists of two parts: the models and the empirical study.

We first set up four linear models. The first and second models intend to determine whether global warming alone has an impact on rural-urban migration and net emigration, respectively. While the third and fourth models examine the impact of global warning on rural-urban migration and net emigration respectively, when global warming is associated with other independent variables or cofactors such as population growth rate and gross domestic product (GDP) growth rate.

In the empirical study, four hypotheses on the sign of the coefficients of the global warming variable are stated. The Ordinary Least Squares (OLS) technique is used to run the econometric regressions of the four models in order to test the hypotheses. To determine whether an increase in rural-urban migration and GDP growth rate matters in net emigration, we also run an econometric regression with the OLS technique in which net emigration is the dependent variable, and rural-urban migration and GDP growth rate the independent variables.

Models

In this study, we present four linear models :

$$U_i = \alpha_1 + \beta_1 W_i, \ i = 1, \dots 6 \tag{1}$$
$$M_i = \alpha'_1 + \beta'_1 W_i, \ i = 1, \dots 6 \tag{2}$$
$$U_i = \alpha_2 + \beta_2 W_i + \gamma P_i + \delta G_i, \ i = 1, \dots 6 \tag{3}$$
$$M_i = \alpha'_2 + \beta'_2 W_i + \gamma' P_i + \delta' G_i, \ i = 1, \dots 6 \tag{4},$$

where U_i and M_i, the dependent variables, are respectively the number of rural-urban migrants and that of net emigrants for country i; W_i, P_i, and G_i, the independent variables, are respectively the global warming potential index, the population growth rate and the GDP growth rate; α_1, α'_1, α_2, α'_2 the constants; and β_1, β'_1, β_2, β'_2, γ, γ', δ and δ' the coefficients of the independent variables.

Empirical study

The study was conducted in Paris (France) in 2007. In this study, we state four hypotheses which will be tested, and indicate how and where the data were collected.

Hypotheses

The four hypotheses are as follows :

We would like to know whether

- An increase in global warming alone results in an increase in the number of rural-urban migrants, i.e. whether the coefficient β_1 is positive;
- An increase in global warming alone results in an increase in the number of net emigrants, i.e. whether the coefficient β'_1 is positive;
- An increase in global warming associated with the growth rate of population and that of the GDP results in an increase in the number of rural-urban migrants, i.e. whether the coefficient β_2 is positive;
- An increase in global warming associated with the growth rate of population and that of the GDP results in an increase in the number of net emigrants, i.e. whether the coefficient β'_2 is positive.

Data collection

There are 8 forefront Sub-Saharan countries, namely Burkina Faso, Chad, Gambia, Mali, Mauritania, Niger, Senegal and Sudan. However, Sudan and Gambia were excluded from the study. Sudan was excluded due to the civil war which has been raging there for more than a decade, and Gambia because of its incomplete data set.
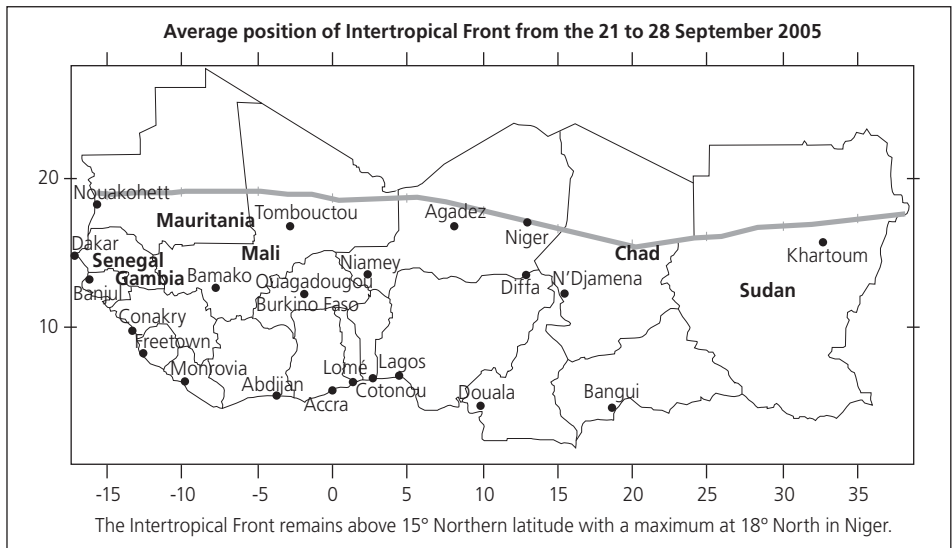
The data of the remaining 6 countries are from the period 2000-2005. The data on the GDP growth rate, the population growth rate and the number of rural-urban migrants were obtained from the United Nations (UN) National Accounts Main Aggregate Data (2005), the UN World Population Prospects (2002), the UN World Urbanization Prospects (2003) and Bouare (2006), while the data on global warming and the number of net emigrants were obtained from the UN Environmental Programme (2007). The global warming potential index is based on the emission of total greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6), excluding land-use change

and forestry. This index is calculated as the ratio of the radiative forcing that would result from the emissions of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a period of 100 years. CO_2 is the carbon dioxide, N_2O the nitrous oxide, HFCs the hydrofluorocarbons, PCFs the perfluorocarbons and SF_6 the sulfur hexafluoride. While the number of net migrants, according to the UN Environmental Programme, is the number of immigrants minus the number of emigrants. Therefore, the number of net emigrants (i.e. number of emigrants minus number of immigrants) is obtained by taking the opposite value of the number of net migrants, i.e. minus the number of net migrants.

A map of the 6 countries is displayed in Figure 6, indicating their positions with respect to the average intertropical front.

Figure 6 Map of Forefront Sub-Saharan Countries

Average position of Intertropical Front from the 21 to 28 September 2005

The Intertropical Front remains above 15° Northern latitude with a maximum at 18° North in Niger.

We can now present the econometric results obtained by using the OLS technique.

RESULTS

Estimates of the coefficients of the independent variables of equations (I), (II), (III) and (IV) are in Table 1. The dependent variable of equations (I) and (III) is the number of rural-urban migrants, while that of equations (II) and (IV) is the number of net emigrants.

The coefficients of global warming in equations (I) and (II) are positive, but not statistically significant. Moreover, equations (I) and (II) are misspecified since their R^2 are respectively 23% and 6.5%. Whereas the independent variables of equations (III) and (IV) explain 88.2% and 88.4% of rural-urban migration and net emigration, respectively. In addition, the coefficients of global warming are positive in equations (III) and (IV), and statistically significant at 5% level. The two other independent variables associated with global warming, i.e. population growth rate and GDP growth rate are also positive and statistically sgnificant at 5% level.

Table 1 Estimation of linear rural-urban and net emigration models

	(I)	(II)	(III)	(IV)
Constant	127.99	-123.61	-1770.42	-2099.40
Global warming	26.93 (1.10)	15.87 (0.53)	72.40* (3.56)	57.50* (2.56)
Population growth rate	----	----	486.48* (3.23)	502.92* (3.02)
Gross domestic Product (GDP) growth rate	----	----	50.96* (2.94)	71.73* (3.75)
R^2	0.23	0.065	0.882	0.884

NB (*) means statistically significant at 5% level.

Source of rural-urban migration data UN World Population Prospects (2005), UN World Urbanization Prospects (2005) and Bouare (2006). Net emigration and Global warming data: UN Environmental Programme (2007). Population growth rate data: UN World Population Prospects (2005) and Bouare (2006). Gross domestic Product growth rate data: UN Statistics Division – National Accounts Main Aggregate Database (2005) .

The estimates of the coefficients of the independent variables of equation (V) are in Table 2. The dependent variable of equation (V) is the net emigration. While the independent variables are rural-urban migration and GDP growth rate which are positive and statistically significant at 5% and 10% levels, respectively.

Table 2 Estimation of linear net emigration model

	(V)
Constant	-336.95
Rural-Urban Migration	0.88* (4.36)
Gross Domestic Product (GDP) Growth Rate	17.84** (1.94)
R^2	0.91

NB (*) means statistically significant at 5% level; (**) means statistically significant at 10% level.

Source of rural-urban migration data UN World Population Prospects (2005), UN World Urbanization Prospects (2005) and Bouare (2006). Net emigration and Global warming data: UN Environmental Programme (2007). Population growth rate data: UN World Population Prospects (2005) and Bouare (2006). Gross domestic Product growth rate data: UN Statistics Division – National Accounts Main Aggregate Database (2005) .

These results call for a discussion.

DISCUSSION

The discussion evolves around the following four points.

First, concerning the assessment of the quantitative impact of global warming on migration in forefront Sub-Saharan countries, as far as the first and second hypotheses are concerned,

it was found that global warming alone is not significantly related to rural-urban migration and net emigration. This may be due to the fact that global warming (a natural disaster) occurs gradually and frequently in human history. As a result, people adjust to it and do not feel the need to move away from their places of residence. This has been seen for instance in California (USA) and Japan where continued occurrence of earth quakes do not make people leave their places of residence to move in urban areas or in other countries. Similarly, in Florida (USA) despite the frequent occurrence of hurricanes, people by and large do not leave their places of residence even if the insurance companies do not want to insure some of the houses.

However, when global warming is associated with the population growth rate and the GDP growth rate, global warming becomes positively and significantly related to rural-urban migration. In other words, with regard to the third hypothesis, an increase in global warming results in an increase in rural-urban migration. This may be due to the fact that when a natural disaster (global warming) is associated for instance with an increase in economic activity in a country (i.e. increase in the GDP growth rate) which generally takes place in urban areas in Sub-Saharan countries, people move from rural to urban areas. This rural-urban migration related to GDP growth rate is supported by the literature (Bouare, 2006; Gado, 1998). Similarly, when a natural disaster is associated with an increase in the population growth rate of the country, people move from rural to urban areas where there are likely to find better living conditions. This rural-urban migration related to population growth rate is also supported by the literature (Gillis *et al.*, 1983).

Again, when global warming is associated with the population growth rate and the GDP growth rate, global warming becomes positively and significantly related to net emigration. In other words, with regard to the fourth hypothesis, an increase in global warming results in an increase in net emigration. It could be that people first leave rural areas for urban areas in their country. This is substantiated by the significant coefficients of the independent variables in equation (III). It might be that the aim of this first migration for the bulk of them is to accumulate an initial capital. Then, with this initial capital, they leave urban areas to settle in foreign countries. This is supported by the estimates of equation (V), which show that an increase in rural-urban migration and in GDP growth rate results in an increase in net emigration.

Second, the technique used in our cross-sectional study can be applied to one country to study its rural-urban migration and net emigration when a time series data are available.

Third, a limitation of our cross-sectional study is that it is probably suitable for countries within the same climatic zone.

Fourth, the main finding of the study is that population growth rate and GDP growth rate are cofactors of global warming whose increase with that of global warming induce rural-urban migration and net emigration.

CONCLUSION AND POLICY IMPLICATIONS

In this paper, we set up four linear models to determine whether an increase in global warming increases rural-urban migration and net emigration. We found that global warming alone is not significantly related to rural-urban migration and net emigration. However, when

global warming is associated with cofactors such as population growth rate and GDP growth rate, global warming induces both rural-urban migration and net emigration. In the light of these results and given that an increase in the GDP growth rate is beneficial for a country as well as a moderate increase in its population growth rate that leads to the acquisition of more human capital, the policy should focus on reducing rural-urban migration, net emigration and global warming. Consequently, the policy should be as follows:

- Create economic poles in rural areas that are based on the demand of the goods which are produced the most in these areas (i.e. bring to rural people a source of economic growth) in order to deter people from moving from rural to urban areas in the event of an increase in global warming, population growth rate and GDP growth rate. This may reduce the rural-urban migration induced by global warming;
- Following the Kyoto Protocol and Stern Review, reduce the greenhouse gases due to human activities by reducing in particular the emissions of carbon dioxide which is their greatest component. This may reduce rural-urban migration and net emigration induced by global warming;
- Reduce the greenhouse gases due to solar cycle when the earth is closer to the sun by conceiving a technology which can send back to the sun some of the infrared rays before they cross the stratosphere, and a technology that can absorb and stock on a large scale a great deal of solar energy in order to replace fossil fuels such as coal and petroleum with clean solar energy. This may reduce rural-urban migration and net emigration induced by global warming.

This policy could help reduce rural-urban migration and net emigration induced by global warming in forefront Sub-Saharan countries.

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