Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.2, No.7, 2011

Climate Change and Economic Development in Sub-Saharan African Countries: A Panel Econometric Approach

MOBOLAJI, H. I
Department of Economics and Financial studies,
Fountain University, Nigeria
Tel: +234 805 210 7885 E-mail: hakeem.mobolaji@gmail.com

HASSAN, A. O
Department of Political Science and Industrial Relation
Fountain University, Nigeria
Tel: +234 818 184 4222 E-mail: oahassan@yahoo.co.uk

SOFOLUWE, N. A
Department of Agricultural Economics,
Obafemi Awolowo University, Ile-Ife, Nigeria
Tel: +234 805 987 4022 E-mail: afolabiadisa@yahoo.com

ADEBIYI, S.O (Corresponding author)
Department of Economics and Financial studies,
Fountain University, Nigeria
Tel: +234 803 368 2722 E-mail: lanre18april@gmail.com

Received: October 19, 2011

Accepted: October 29, 2011

Published: November 4, 2011

Abstract
This paper attempts to empirically investigate the impact of climate change on economic development in Sub-Saharan African countries. It is a simple linear panel model using three estimation techniques, fixed effect, random effects and Maximum likelihood method. The Hausman test was also conducted to choose the most appropriate technique.
In all, the paper finds that climate change impacts positively on the economic development in the region. The paper further recommends more adaptation as against mitigation measures, as many SSA countries already have some forms of indigenous adaptation measures which are relatively more manageable and less costly technological options in dealing with climate change.
Keywords: Climate, economic development, Africa

1. Introduction

One of the issues that have attracted the attention of policy makers and academia in the recent time is the issue of climate change. Its impact on the economy is a topical issue for investigation among researchers. There are strong projections of the adverse effects of climate change on fragile Sub-Saharan African (SSA) countries. The implication of this is further heightened on their appropriate compensation scheme that is expected from many developed pollutant countries. The economics of externalities is fresh in the literature and appropriate compensation scheme is inconclusive in the literature.
Policy makers and academicians are increasingly concerned with the effects of climate change on present and future economic growth

This study is quite necessary and timely to enable SSA countries to develop appropriate economic policy framework to counter or address the issues and challenges of climate change to several SSA economies.

In terms of economic analysis, the impact of climate change has about four different channels by which it affects SSA economies; these are its impact on agricultural output and food security, its impact on poverty, on trade competitiveness and economic growth among other channels.

Odingo (2009) argues that anthropogenic (human-induced) climate change is the greatest culprit in the current global warming through agriculture and fossil fuel use. He further argues that most of the observed increase in the globally averaged temperatures since the mid-20th century is likely due to the observed increase in anthropogenic greenhouse gas concentrations. He further stressed that discernible human influences now extend to other aspects of climate, including ocean warming, continental average temperatures, temperature extremes and wind patterns.

Data from the International Panel on Climate Change (IPCC) supports the fact that it is extremely unlikely that global climate change of the past 50 years can be explained without external forcing, and not mere natural cause alone.

From the literature the contribution of SSA to climate change problem is minimal; however, it bears substantial adverse effects. One of the issues that have been identified is that SSA countries and their policy makers have made little conscious effort to include or mainstream climate change into respective domestic economies economic planning. Thus, the gap in the literature is to find an empirical evidence of impact of climate change on SSA economies. Few empirical studies on this issue have been from the Western countries perspective, and apparent dearth of empirical studies from the African researchers who are directly bear the incidence of this climate change. This study is an attempt to fill the research vacuum and contribute to meaningful dialogue in this very important field.

This is so because the region has several landlocked countries, small and fragile economies with worsening water situation and high poverty rate and high deprivation index in the region. The water stress would be worsened, the climate variability could also worsen the ecosystems (mangroves and coral reefs at the coast e.g) with additional consequences for fisheries and tourism and its impact on precarious health condition is much.

One of the policy options left for African leaders is to have mitigation efforts that would cost less or nothing rather than waiting for Western Leaders that have been reluctant to fulfil promises to help vulnerable African countries since the signing of the United Nations Framework Conventions on Climate Change (1992). Africans have to develop coping strategies to adapt to climate change. The factors that determine the adaptive capacity of a nation include technology, education, information skills, infrastructure, access to resources and various psychological factors and management capabilities.

Shah et al (2009) find that bio-fuel production in some countries[1] will deplete the forest cover and upset the ecological rain catchments balance. It may result in import dependence as climate change continues to impact negatively on food production. Climate change further worsens the agricultural yield per hectare of land. They contend that Africa countries do not have the necessary financial resources to engage on mitigation, thus, the first priority for these countries is to focus on adaptation strategies. It was equally observed that SSA countries have contributed the least to climate change but the worst hit or affected by climate change due to their high level of vulnerability. He concludes that the SSA countries should also use the IPCC data to assess climate change impacts on their economies and estimate the cost of adaptation.

There are two major strategies suggested in the literature as policy responses to climate change, these are adaptation and mitigation strategies. Most SSA economies are predominantly based on agriculture, which is the most climate sensitive, while the region low per capita and persistent high poverty rates present a major challenge for adapting to climate change. Developing responses to climate change if not urgently treated could slow the pace of achievement of the Millennium Development Goals (MDGs) in the region.

Ajaye (2009) documents that climate change has already led to average crop losses. He concludes that countries need to adapt to climate change and then mitigate its impacts on their domestic economies. There are major constraints to adaptation, which include lack of information, institutional deficiencies, biophysical deficiencies (ecosystem degradation), future development in the energy markets including

bio-fuels, financial constraints, various types of adaptation costs, such as transition cost and equilibrium costs.
The study recommends that Africa should push for expansion of the scope of the Clean Development Mechanism (CDM) to include agricultural practices. That the post-Kyoto negotiations should include the aspect that SSA is the lowest polluter and has contributed the least to global warming. It is also necessary to intensify and improve the negotiations for economic Partnership Agreements (EPAs) and the next Doha Round as a means of improving Africa's medium term
SSA should enhance steps at investing in mass public transportation and improve urban planning. It has to review its lifestyle in relation to consumption of water and electricity use and how the two are priced. Government should encourage environmentally friendly firms by giving them a tax break for the period they are assessed as being environmentally friendly. There is need for regular agencies to assess the level of environmental pollution of each firm or households. The government can also initiate climate insurance policy through public private partnership. The SSA should build its adaptive capacity, set up early warning systems, and improve water storage and farming system. Invest in rural infrastructure and market institutions, improve physical infrastructure and construct defensive structures like mangroves belts, tree shelterbelts and others.

Brown et al 2009 observed that drought and flood are two major consequences of climate change. Drought is the single largest cause of death to natural disasters, at approximately 50% of the global total and floods account for the highest property loss. They employed an econometric approach and find that the sensitivity of GDP to climate change is substantial in the region. Precipitation (due to drought) has the most important climate change effect on the GDP or economic growth. About a third of the countries under reviewed reports significant negative impacts from drought.

Protection against climate hazards is therefore an essential; intervention that can provide benefit and reduce current climate vulnerability is a first step in adaptation policy / strategy. Each country is expected to invest in climate information systems/ early warning systems, diversification of crops and livelihoods; financial risk transfer (Index insurance), market development, transportation and storage. Uncertainty of future project requires a climate risk management approach and managing current variability. Finally, government should mainstream climate change risk assessment into all aspects of policy planning.

The Kyoto protocol was agreed upon in 1997 and signed ratified and became effective in February 2005, with a sole aim of securing legally binding commitments for the reduction of greenhouse gases. Six years later, how has SSA faired? A vacuum this paper tries to contribute. The SSA countries are members of both the UNFCCC and naturally bound by its principles and provisions, many of which expected every nation and people to protect the climate system for the benefit of the present and future generations on the basis of equity in accordance with their "common but differentiated responsibilities and respective capabilities"
One of the goals of UNFCCC is to identify the developing countries that are vulnerable to the adverse impacts of climate change and give them preferential treatment under the convention with promises of technology transfer and other forms of economic assistance (see article 2 of UNFCCC).

Under the agreement the developed countries are expected to "take precautionary measures to anticipate, prevent or minimize the causes of climate change and to mitigate its adverse effects". They are supposed to take cost effective measures to ensure global benefits at the lowest possible costs.

Africa's major economic sectors are already vulnerable to existing climate variability. This vulnerability is further exacerbated by challenges such as endemic poverty, poor governance, weak institutions, inadequate health services, limited access to capital, markets, infrastructure and technology, ecosystem degradation and complex disasters and conflicts.

SSA countries are to undertake some voluntary mitigation programmes that do not conflict with their development needs. Africa's total mission of greenhouse gases is miniscule (Odingo, 2009), South Africa is

the most industrialized country in the region, and accounts for 40% of CO2 emissions from fuel combinations, this represents only 1.2% of the total global emission. The rest of SSA produces the remaining 60% of CO2 emissions. Though some oil producing countries like Angola, Gabon, and Nigeria have the potential to increase their energy production from fossil fuels and thereby contributing to global CO2 emissions in the future.

Some of the policy options available include the fact those responsible for economic development programmes can help to promote the environmentally friendly technologies that were proposed under the Gleanagles Plan of Action in 2005. These include: Transforming the way energy is used, namely resorting to energy efficiency, fostering research and development of lower emission technologies; financing the economic transition to cleaner energy and managing the effects of climate change.

In the future, any economic model or assumptions made now without due recognition of impacts of anthropogenic climate change will need to be revised. In fact, any economic development will be forced to factor climate change in its analysis. The IPCC projections suggest that many SSA countries would experience increase aridity and crop failure due to rising temperatures. This may eventually lead to drought and floods and this may also affect biodiversity. The reports contend that some of these impacts are abrupt or irreversible, depending on the rate and magnitude of the climate change. This may also lead to species extinction which can affect the biodiversity programmes in the region. Terrestial ecosystems will be the first to be affected, followed by marine and freshwater ecosystems. The Economic Planners in SSA need to recognise this. Some of these countries may equally have more precipitation with its negative impacts.

Consumption patterns influence the emission of GHGs in most countries, thus IPCC (2007) has suggested the possibility of addressing changes in lifestyle and behaviour patterns that can contribute to climate change mitigation. One of these suggestions includes changes in occupant behaviour, cultural patterns and consumer choice in buildings. Reductions of car usage and adoption of efficient driving styles in relation to urban planning and availability of public transport, behaviour of staff in industrial organizations in the light of reward systems.

IPCC (2007) documents 0.2% reduction in GDP for emissions of 590-710ppm of CO_2 it further suggests that it is better for countries to participate in common sense mitigation that cost virtually nothing. These practices include energy saving in building and in transport sectors and any other good practice programmes whose cost element is within reach. It may also engage some adaptation measures such as vulnerability assessments, prioritization of actions, financial needs assessments, capacity building and response strategies (UNFCC 2007). Other measures to enhance action on adaptation include:

- Risk management and risk reduction strategies, including risk sharing and transfer mechanisms such as insurance.
- Disaster reduction strategies and means to address loss and damage associated with climate change
- Economic diversification to build resilience

Environmentally friendly technologies are needed to enable SSA to cope with the impacts of climate change. Until the region acquires such technologies, she may not be able to optimally mitigate climate change. These technologies need to be acquired, assimilated and adopted by SSA, through concessional rates, vibrant educational system and strong linkage with advanced countries. The developed countries must also offer appropriate mechanisms and incentives to facilitate this acquisition, deployment and diffusion of these modern technologies as provided by the Kyoto Protocol.
Stern (2006) highlights the role of technological change in mitigating the adverse effects of climate change.
In conclusion, though climate change is a topical issue and challenge facing SSA region, but certainly it is not the greatest challenge, as there are other numerous development challenges facing the region such as high poverty rate, poor health facility, low educational attainment, weak institutions and high corruption among others, however, the challenge of climate change could worsen the developmental problems and slow the pace at which the region moves towards the attainment of the MDGs. The impact of climate change is directly felt on its impact on poverty level as it accentuates it

1.1 Attitude towards Climate Change

In fact UNIDO (2004) casts doubt on the ability of SSA to achieve the MDGs let alone mitigate climate change. For SSA to achieve this, it needs the support of the international community. Climate change mitigation efforts would only be effective when the region breaks out of the vicious cycle of poverty. Due to the precarious economic situation in SSA, issue of climate change has not attracted much attention in the literature and among policy makers or at worst has not entered the priority list of many SSA countries. This attitude has further made the developed countries (who are the worst polluters) to take appropriate mitigation measures or at worst implement the Kyoto protocols, thus in the two ends, the SSA are worse off and merely bore the negative externality with no or inadequate compensation.

This inactive or passive response however began to change in 2006, when Nicolas Stern ignite the passion to rescue SSA from the imminent danger from climate change when he addressed the issue among other African leaders and economists about the importance of climate change to economic development in the region. This position was further corroborated by IMF (2007) where it clearly spells the impact of climate change to economic development during the Bali conference in Indonesia. The conference observed that many SSA countries would prefer adaptation measures more than mitigation measures, as many of these countries already have some forms of indigenous/traditional adaptation measures. This can then be complemented with the modern adaptation techniques.

Brown et al (2009) using national level precipitation statistics that incorporates spatial and temporal variability within each country, links precipitation, temperature and economic growth to identify impacts of climate change on SSA economies and records substantial negative impacts.

A climate risk assessment is used to provide the foundation for adaptation planning. The vulnerabilities of SSA economies are investigated using econometric analysis, Stern (2007) estimated that negative consequences of climate change are sizeable and outweigh the certain costs of acting now to avoid those consequences. Nordhaus (2006), Tol (2002), Nordhaus and Boyer (2000) are among early scholars that to document the impact of climate change on economic development. Though most of these efforts focus on changes in temperature, and this primarily depends on the sensitivity of a country's economy to climate.

Many SSA countries are tropical countries that are on an average less wealthy and more dependent on agriculture, face more challenging baseline climate in terms of rainfall variability and have less developed infrastructures and lack financial instruments such as insurance and markets to mitigate these effects. The region also carries a disease burden that is exacerbated by epidemic outbreaks of malaria linked to climate variability (Brown et al 2009).

2. Literature Review on Climate Change and Economic Development

Studies on the climate change-development nexus often take two approaches, these are the enumerative and integrated (Fankhauser and Tol, 2005). The enumerative approach focuses on the effects of climate change on a particular sector of an economy and then aggregates these effects. The major limitation of this approach is that it overlooks the interlinkages among sectors, or the contagious effects of several interrelated sectors.

The integrated approach models this nexus through parametization of the climate effect on economies as a whole in a simple way. The limitation of this approach is the presumption that climate effect is general or similar in several countries, but it is obvious that climate effect operate differently in different regions. Despite this limitation, the integrated approach is still relatively more favoured.

The effect of climate variability is a significant component of the geography effect noted in the development literature. Sachs (2001), Easterly and Levine (2003), Rodrik et al (2004) all identified the impact of geography in economic development. Sachs (2001) identifies climate variability as one of the idiosyncratic challenges of the tropical economies. Brown and Lall (2006) find that inter-annual and intra-annual precipitation variability were significant contributing factors to the variation in global income.

High levels of hydro-climatic variability characterized by drought and floods impair development. Floods destroy o=infrastructure, disrupt transportation and economic flows of goods and services and can lead to contaminated water supplies and outbreak of waterborne disease epidemics. Drought is one of the world's most expensive disasters destroying the economic livelihood and food source for those dependent on the agricultural sector or their own food production.

World Bank (2004) demonstrates that hydrology and rainfall variability have major impacts on economic

development. Grey and Sadoff (2007) find that hydrologic affects on the Ethiopian economy that occurrence of droughts and floods reduced economic growth in Ethiopia by more than one-third.

Walker and Ryan (1990), Dercon (2002) observe that climate variability is a dominant source of consumption risk in small holder rain-fed agriculture in SSA. Zimmerman and Carter 2003 opine that climate change contributes to price variability in regions where markets and transportation infrastructure are poorly developed. They also contend that since the poor have fewer buffers against climate risk through their own assets or financial markets, they tend to experience disproportionate livelihood risk in the face of climate variations. Many empirical analyses use a weighted anomaly standardized precipitation (WASP) index in place of an annual average (Lyon and Barnston, 2005).

2.1 Climate Change- an overview

Climate change is a global problem and requires a global solution. In recent years, addressing climate change has been high on the international policy agenda. There is now a consensus that to prevent global warming from reaching dangerous levels, action is needed to control and mitigate GHG emissions and stabilize their atmospheric concentration within a range of 450–550 parts per million (ppm) (IPCC 2007). The lower bound is widely considered a desirable target and the upper bound a minimum necessary level of mitigation (Stern 2007). The international community is now working toward an international climate regime under the United Nations Framework Convention on Climate Change (UNFCCC) that aims to stabilize GHG atmospheric concentration and provide a long-term solution to the climate change problem through international cooperation based on the principle of common but differentiated responsibility. While the responses of the major current and future GHG-emitting economies under the UNFCCC hold the key, a successful global solution requires the participation of all countries, developed and developing.

Climate change can be broadly described as 'any change in climate over time, whether due to natural variability or as a result of human activity' (IPCC 2007). Natural sources of climate variability include modifications to ocean currents, continental drift and solar and volcanic activity: all these may result in random variation in climate along a continuing average. Such trends in climate are natural, pre-existing and have been experienced on a global scale for thousands of years (CSIRO 2006).

However, more recent usage of the term 'global climate change' (GCC) typically refers to anthropogenically-induced changes to the global climate. In particular, it refers to excess greenhouse gas emissions, such as carbon dioxide (CO2), methane and sulfates, which are produced by industrial activity and the burning of fossil fuels (CSIRO 2006). Plainly speaking, the release of these gases intensifies the natural greenhouse effect of the earth, resulting in the capture of more radiant heat originally sourced from the sun. This produces higher-than-normal levels of global warming via the enhanced greenhouse effect, a situation that has been associated with a number of detrimental consequences.

2.2 Vulnerability to climate change

Reid et al (2007) documents that it is becoming widely acknowledged that poor nations will suffer most from the effects of climate change. This vulnerability stems partly from their geographic location in areas such as drought-prone sub-Saharan Africa or flood-prone Bangladesh. Their capacity to cope with climate change is also lower than that of wealthier nations because of limited financial resources, skills and technologies and high levels of poverty.

The IPCC recognizes Africa as a whole to be "one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity" (IPCC 2007). Besides this, many African countries are heavily dependent on climate sensitive sectors, such as rain-fed agriculture. Issues like food scarcity and inequitable land distribution make the African continent particularly vulnerable. In addition, development challenges like high population growth rates, high prevalence of diseases such as HIV/AIDS and malaria, growing poverty, inadequate technological development and insufficient institutional and legal frameworks to cope with environmental degradation all make it even harder for Africa to cope with additional challenges like climate change (Sokona *et al*. 2001).

Reducing the impacts of climate change on poor countries requires action now, both at the level of reducing greenhouse gas emissions and helping those countries that are particularly vulnerable to climate change to adapt to its impacts. This, however, requires domestic political will, and whilst ministerial rhetoric is often strong, translation into action is usually piecemeal. Predictions of temperature and precipitation changes for vulnerable regions seem to gain little policy traction when it comes to domestic development policies. This

is not because of a shortage of scientific consensus on the realities of climate change. A more probable explanation for the lack of political action is the fact that the multilateral climate change process is complicated and slow, and relies on reaching consensus through negotiation. Policymakers also fear that serious action on climate change will be a domestic 'vote loser', and see climate change as a problem they hope can be avoided within their political lifetime.

One way to tackle these challenges and raise climate change concerns further up the agenda for policymakers is to try to put an economic value on the environmental impacts from climate change. This can both strengthen the argument for early action, and provide evidence to convince the electorates that the lifestyle changes required will actually be of long-term benefit to them and their children. The Stern Review on the Economics of Climate Change, led by the UK Government but global in scope, demonstrated both these arguments to great effect (Stern 2006). Even though some specific assumptions and estimates in the Stern Review have been subject to criticism from other climate economists (see for example Dasgupta 2006; Nordhaus 2006; Tol 2006; Sterner and Persson 2007 and Weitzman 2007), the mainstream economics of climate policy seem to support the fact that on a global level, the estimated costs of starting to reduce emissions today is lower than the expected damages that might otherwise occur (Nordhaus and Yang 1996; Nordhaus and Boyer 1999; Tol 2002; Mendelsohn *et al*. 2000; Yohe *et al*. 2007 and Nordhaus 2006). The Stern Review, for example, suggests that "[t]he costs of stabilising the climate are significant but manageable; delay would be dangerous and much more costly" (Stern 2006).

Even though there is still uncertainty over the magnitude of costs and benefits of reducing emissions on a global scale, there is a general consensus among climate economists that poor countries will be most negatively affected by climate change. Figures that provide a clear message on what climate change impacts can be expected will also be powerful motivators for policymakers in developing countries to start considering climate change as a part of their national development policies; some investments in adaptation today might curtail future climate change costs.

2.3 Climate change and economic growth

The IPCC reports, the Stern Review, and many other studies point out that climate change has important, and in most cases negative effects on ecosystems and humans. However, estimating the consequences of climate change for economic growth, the relationship we are interested in at this point in the argument, is very tricky for various reasons. Climate and weather impact on almost all human activities from leisure to agriculture to industrial production. But even when considering only a few activities, for example agriculture or industrial output, the estimation task remains quite daunting. The main reason is that the impact of climate change will vary with levels of economic development and political capacity of a country, with levels and types of climate change (more/less rain; high/lower temperature; more/less frequent and/or intense storms, etc.). In other words: although economic and political actors will of course respond to climatic conditions by developing and implementing adaptation strategies, their ability to do so depends critically on institutional, economic, and technological capabilities.

The existing literature provides ample evidence that climate change affects economic output (GDP) (e.g. Mendelsohn et al., 1998; Mendelsohn, Dinar & Williams, 2006; Nordhaus & Boyer, 2000; Tol, 2002; Deschenes & Greenstone, 2007; Barrios, Bertinelli & Strobl, 2010). This also suggests that climate change should affect economic growth. If climate change affected only the level of economic output, for example by reducing agricultural yields when temperature rises (precipitation falls), this would imply that subsequent temperature decreases (precipitation increases) – due for example to stringent abatement of emissions – should return the GDP to its previous level. But this is not the case if climate change affects economic growth. The reasons are the following. First, economic growth will be lower even if GDP returns to its previous level because of forgone consumption and investment due to lower income during the period of higher temperature (lower precipitation). In addition, as long as countries spend some resources to adapt to climate change, they incur opportunity costs in terms of not spending these resources on R&D and capital investment. This has negative effects on economic growth. Moreover, given the shortness of the times series used in existing research on climate effects on economic conditions, even slightly persistent effects on the level of output will impact on the sample mean of growth. That is, using economic growth rates will also capture the effects on GDP levels. But using the level of GDP instead of its growth rate may miss the effects on the growth rate. For these reasons we concentrate on climate change effects on

economic growth.
The empirical literature offers some evidence that climate change affects economic growth. For instance, Miguel, Satyanath & Sergenti (2004) find that rainfall growth increases economic growth in Africa. Dell, Jones & Olken (2008), using data on temperature and precipitation for a panel of 136 countries over the period 1950-2003, show that higher temperatures have large negative effects on growth, but only in poor countries, whereas precipitation has no effect. The authors also find that the estimated impact of temperature in poor countries is large – a 1o C temperature increase reduces economic growth by 1.09 percentage points. In summary, we postulate, as supported by the literature, that climate change should have important negative effects on economic growth.

2.4 The economics of climate change impacts: poverty implications
The economic literature on climate change impacts has not always agreed upon the likely welfare impacts of climate change, even when it includes non-market values. However, most of these studies have been concerned only with agricultural impacts in industrialized countries, especially in the USA and Canada (for example, Weber and Hauer 2003; Deschenes and Greenstone 2007; Mendelsohn and Reinsborough 2007). In global studies, there is general agreement that poor countries, particularly those in Africa (Reid 2005; Simms and Reid 2005) will suffer the most from climate change impacts. Economic impact assessment studies at a global level generally conclude that the global benefits of acting today outweigh the global future costs of uncontrolled emissions, particularly because of the high damage estimates for the poor parts of the world (Nordhaus 1994; Nordhaus and Yang 1999; Tol 2002; Mendelsohn *et al*. 2000; Nordhaus 2006 and Stern 2006). Developing countries are often more directly dependent on their natural resource base, implying that climate sensitive sectors in these countries make significant contributions to national GDPs. Winters *et al*. (1998) focus on the economic and welfare impacts of climate change due to changes in agricultural production in different parts of the developing world. The study suggests that Africa in particular, due to low substitution possibilities between imported and domestic foods, will most likely experience significant income losses and a drop in consumption of the low-income households as a result of climate change. Mendelsohn *et al*. (2006) examine the distributional impact of climate change on rich and poor countries and predict that poor countries will be most vulnerable due to their location. Although these studies are insightful, they do not necessarily predict what will happen to particular poor communities within a country. But there are many reasons to believe that poor people in a country will bear much of the burden; they have less access to capital, making it harder for them to adapt to climate change or purchase their way out of reductions in crop productivity by buying food. Many poor people also live in vulnerable locations, such as floodplains and coastal areas, and they often lack access to the social safety nets, which protect wealthier individuals in times of need.

2.5 Climate Change Impacts Economic Growth
According Pearce et al. (1996), Economic research on climate impacts has long revealed that only a limited fraction of the market economy is vulnerable to climate change: agriculture, coastal resources, energy, forestry, tourism, and water. These sectors make up about 5 percent of the global economy and their share is expected to shrink over time. Consequently, even if climate change turns out to be large, there is a limit to how much damage climate can do to the economy.
Most sectors of the global economy are not climate sensitive. Of course, the economies of some countries are more vulnerable to climate change than the global average. Developing countries in general have a larger share of their economies in agriculture and forestry. They also tend to be in the low latitudes where the impacts to these sectors will be the most severe. The low latitudes tend to be too hot for the most profitable agricultural activities and any further warming will further reduce productivity. Up to 80 percent of the damages from climate change may be concentrated in low - latitude countries (Mendelsohn et al. 2006).
Some damages from climate change will not affect the global economy, but will simply reduce the quality of life. Ecosystem change will result in massive shifts around the planet. Some of these shifts are already reflected in agriculture and timber but they go beyond the impacts to these market sectors. Parks and other conservation areas will change. Animals will change their range. Endangered species may be lost. Although these impacts likely lead to losses of nonmarket goods, it is hard to know what value to assign to these

effects. Another important set of nonmarket impacts involve health effects. Heat stress may increase. Vector‐borne diseases may extend beyond current ranges. Extreme events could threaten lives. All of these changes could potentially affect many people if we do not adapt. However, it is likely that public health interventions could minimize many of these risks. Many vector‐borne diseases are already controlled at relatively low cost in developed countries. Heat stress can be reduced with a modicum of preventive measures. Deaths from extreme events can be reduced by a mixture of prevention and relief programs. As the world develops, it is likely that these risks may involve higher prevention costs, but not necessarily large losses of life. Further, winters lead to higher mortality rates than summers so it may well be that warming has little net effect on health. Agricultural studies in the United States suggest that the impacts of climate change in mid‐latitude countries are likely to be beneficial for most of the century and only become harmful towards the end of the century (Adams et al. 1990; Mendelsohn et al. 1994). In contrast, there will be harmful impacts to agriculture in African countries (Kurukulasuriya and Mendelsohn 2008a), Latin American countries (Seo and Mendelsohn 2008a), and China (Wang et al. 2009) starting almost immediately and rising with warming. The overall size of these impacts is lower than earlier analyses predicted because of the importance of adaptation. Irrigation (Kurukulasuriya and Mendelsohn 2008b), crop choice (Kurukulasuriya and Mendelsohn 2008c; Seo and Mendelsohn 2008b; Wang et al. 2009), and livestock species choice (Seo and Mendelsohn 2008c) all play a role in reducing climate impacts. The studies above document that current farmers are already using all of these methods to adapt to climate today in Africa, Latin America, and China.

Other sectors that were originally expected to be damaged include timber, water, energy, coastal, and recreation. Forestry models are now projecting small benefits in the timber sector from increased productivity as trees respond positively to a warmer, wetter, CO2 enriched world (Sohngen et al. 2002). Water models tend to predict there will be damages as flows in major rivers decline. However, the size of the economic damages can be greatly reduced by allocating the remaining water efficiently (Hurd et al 1999; Lund et al. 2006). Energy models predict that the increased cost of cooling will exceed the reduced expenditures on heating (Mansur et al. 2008). Several geographic studies of sea level rise have assumed there would be large coastal losses from inundation (Nichols 2004; Dasgupta et al. 2009). However, careful economic studies of coastal areas suggest that most high‐valued coasts will be protected (Neumann and Livesay 2001; Ng and Mendelsohn 2005). The cost of hard structures built over the decades as sea levels rise will be less than the cost of inundation to urban populations. Only less‐developed coastal areas are at risk of inundation (Ng and Mendelsohn 2006). Initial studies of recreation measured the losses to the ski industry of warming (Smith and Tirpak 1989). Subsequent studies of recreation, however, noted that summer recreation is substantially larger than winter recreation and would increase with warming (Mendelsohn and Markowski 1999; Loomis and Crespi 1999). The net effect on recreation is therefore likely to be beneficial. As economic research on impacts has improved, the magnitude of projected damages from climate change has fallen. Early estimates projected that a doubling of greenhouse gases would yield damages equal to 2 percent of GDP by 2100 (Pearce et al. 1996). More recent analyses of impacts suggest damages are about an order of magnitude smaller (closer to 0.2 percent of GDP) (Tol 2002a,b; Mendelsohn and Williams 2005). The reason that damages have been shrinking is that the early studies (i) did not always take into account some of the benefits of warming to agriculture, timber, and tourism; (ii) did not integrate adaptation; and (iii) valued climate change against the current economy. At least with small amounts of climate change, the benefits appear to be of the same magnitude as the damages. Only when climate change exceeds 2 degrees Celsius are there net damages. Many early studies assumed victims would not change their behavior in response to sustained damages. More recent studies have shown that a great deal of adaptation is endogenous. If government programs also support efficient adaptations, the magnitude of damages falls dramatically. Finally, by examining the effect of climate change on the current economy, early researchers made two mistakes. First, they overestimated the relative future size of sectors that are sensitive to climate such as agriculture. Second, they underestimated the size of the future economy in general relative to climate effects.

Economic analyses of impacts also reveal that they follow a dynamic path, increasing roughly by the square of temperature change (Tol 2002b; Mendelsohn and William 2007). The changes over the next few decades are expected to result in only small net effects. Most of the damages from climate change over the next hundred years will occur late in the century. These results once again support the optimal policy of starting

slowly with climate change and increasing the strictness of regulation gradually over time.

2.6 Mitigation Costs

The literature on mitigation predicts a wide range of costs. On the more optimistic side, there are a number of bottom - up engineering studies that suggest mitigation may be inexpensive. Some studies argue that one could even stabilize greenhouse gas concentrations at negative costs (IPCC 2007b). The engineering studies suggest one could reduce emissions by 20 to 38 percent by 2030 for as little as $50 per ton of CO2 (IPCC 2007b). There is even a super - optimistic technical change camp that argues emissions could be cut by 70 percent by 2050 for as little as $50 per ton of CO2 (Stern 2006).

The empirical economic literature suggests mitigation cost functions are price inelastic (Weyant and Hill 1999). Using today's technology, the average abatement cost for a 70 percent reduction in carbon in the energy sector is estimated to be about $400 per ton of CO2 (Anderson 2006). The short - run mitigation function is very price inelastic. The long run is less clear. With time, it is expected that the short - run marginal cost curve for mitigation will flatten.

However, whether it ever gets as flat as the optimistic engineering models project is not clear. An inelastic short - run marginal cost function implies that large reductions of emissions in the short run will be very expensive. There simply is no inexpensive way to reduce emissions sharply in the short run. Renewable energy sources such as hydroelectricity have largely been exhausted. Solar and wind power are expensive except in ideal locations and circumstances. Other strategies such as shifting from coal to natural gas can work only in the short run as they cause more rapid depletion of natural gas supplies.

In the short run, a rushed public policy is likely to be inefficient. It will likely exempt major polluters as Europe now does with coal. Very few national mitigation programs regulate every source of emission. Most countries have sought to reduce emissions in only a narrow sector of the national economy.

Rushed programs will likely invest in specific technologies that are ineffective, such as the United States has done with ethanol. Ethanol produces as much greenhouse gas as gasoline. The inelasticity of the marginal cost function implies that mitigation programs that are not applied universally will be very wasteful.

Regulated polluters will spend a lot to eliminate a single ton while unregulated polluters will spend nothing. Universal participation also requires that all major emitting countries be included. The signatory countries that limit emissions under the existing international Kyoto agreement are responsible for only about one quarter of global emissions. The United States and China generate another one half of emissions and all the remaining developing countries approximately emit the other quarter. Whereas Kyoto countries are beginning to spend resources on mitigation, non - Kyoto countries spend little to nothing. Even within the Kyoto countries, many countries are failing to reach their targets. By failing to get universal application of regulations, the current regulations are unnecessarily wasteful. Without near universal participation, the cost of mitigation doubles (Nordhaus, 2008). In fact, the current Kyoto treaty is so ineffective that global emissions are rising at the pace predicted with no mitigation at all. Global CO2 emissions in 2006 were 8.4 gigatons of carbon (GtC).

Stern and other climate advocates recommend that strict regulations be placed on emissions immediately. Stern recommends regulations that would increase the marginal cost of emissions to $300 per ton of CO2. The stricter regulations would reduce emissions by 40 GtC per year (70 percent) by 2050. If the marginal cost does not fall, the cost of this program will be $1.2 trillion per year by 2050. Of course, it is likely that long - term marginal costs will be lower with technical change. Assuming that costs fall by 1 percent per year, the marginal cost would fall to $200 per ton of CO2 by 2050. The overall cost of the Stern program would be $800 billion per year in 2050. The present value of mitigation costs in the Stern program is estimated to be $28 trillion (Nordhaus 2008).

The optimal regulations that minimize the present value of climate damages and mitigation costs are more modest. They would begin with prices closer to $20 per ton of CO2 then rise to $85 per ton by 2050 (Nordhaus 2008). That would lead to a 25 percent reduction in greenhouse gases by 2050 rather than the 70 percent reduction in the Stern program. The present value of the global mitigation costs of the optimal program this century is estimated to be $2 trillion (Nordhaus 2008). These costs are an order of magnitude

less than the cost of the Stern program.

3. Methodology

This study employs micro panel data framework to allow for differences in the form of unobserved individual country effect. Panel study has a number of advantages over time series or cross-sectional studies. These include its ability to control for individual heterogeneity as well as state and time invariant variables which are not possible with either time series and cross sectional study (Baltagi, 1995). Further, it gives more informative data, more variability, less co-linearity among variables, more degree of freedom and efficiency.

The fixed effect (FE), random effect (RE) and Hausman-test based on the difference between fixed and random effects estimators were conducted. The fixed effect is appropriate if we are focusing on a specific set of firms or countries and our inference is limited to the behaviour of these sets of countries. Although FE is more appropriate, it is often observed that there are too many parameters in the model and thus the possibility of loss of degree of freedom that can be avoided by assuming that the individual effect is random. The random effects (RE) model is an appropriate specification when drawing a sample out of a large population. The test revealed that the random effect is the better estimation method. However, a maximum likelihood estimation method was also used to confirm the robustness of the model.

3.1 Data sources and analysis

Data on Carbon dioxide (CO_2) emission and GDP per capita used for this study were drawn from the World Bank data base for the period of 2006-2007. In all, we have 45 countries of Sub-Sahara Africa in the sample.

3.2 The empirical model

The empirical model is represented by the real GDP per capita growth rate (y) and is assumed to be affected by the rate of CO_2 emission (C). Thus, we specify a simple growth model where the economic growth is influenced by

$$y = f(C).$$

The model

$$\Delta/Y_{it} = \alpha_0 + \beta_1 C_{it} + \varepsilon_{it}$$

where

Y= dependent variable measured by the growth rate of the real GDP per capita
α = intercept
β = parameter to be estimated
C = carbon dioxide (CO_2) emission
ε = error term
t = 2 (number of years)
i = 45 (number of countries)

From the above specification, a theoretical a priori expectation is that CO_2 emission has negative impact on growth; hence, we expect β_1 to be negative and significant indicating that higher CO_2 emission retard growth.

4. Results and Discussion

The estimation results are presented in Table I. The diagnostics tests such as R^2, Likelihood Ratio, Chi-Square and estimated value for the Log-likelihood functions are generally satisfactory. The explanatory variable accounted for about 82 percent of the variations in the economic growth of the sub-Saharan Africa countries suggesting high predictive ability of carbon dioxide emission. The overall fit, expressed by the likelihood test, is high and significant.

The coefficient of carbon dioxide emission is positive and statistically significant at 5 per cent. A unit increase in industrial growth associated with CO_2 emission would increase growth by 0.79. This result indicates direct relationship between increasing industrial growth and economic growth. It further indicates that economic growth necessitates higher amount of energy consumption and thus carbon dioxide and other pollution emission. Essentially, all countries that experience economic growth also reports rising carbon

dioxide emission (Karlsson *et al*. 2002). Similar studies have found that carbon dioxide emissions have grown in line or faster than GDP in India and Brazil over the past 30 years, and also Mauritius- a sub Saharan nation (Boopen and Vinesh, 2010).

Although the positive relationship may be erroneously interpreted as suggesting that CO_2 impact positively on economic growth, however, the real effect is that higher CO_2 emission only indicates higher development of industrial sector.

It is expected that as economic development accelerates with the intensification of agriculture and other resource extraction, the rate of resource depletion begins to exceed the rate of resource regeneration, and waste generation increases in quantity and toxicity. This leads to increase in CO_2 emission. This is more plausible for developing sub-Saharan Africa countries with much dependent on available natural resource exploration.

See Table 1

5. Conclusion

SSA contributes very little to the greenhouse gas emission that drive global warming, due to high level of vulnerability in the region, mitigation of climate change through GHG reduction should be of lower priority than adaptation to the adverse effects.

The region's ability to manage climate variability can be improved; however, they propose improving the ability of economies to manage their current climate challenges is the foundation of adaptation. Climate risk assessment is a process that facilitates the identification and management of climate risks. By successfully managing current climate risks, economic growth can be engendered and countries should be in a better position to manage future challenges. Increasing the vulnerability of the region to gaseous emissions through increased industrial development is very likely to enhance economic growth but increased gaseous emission without corresponding industrial activities may enhance the vulnerability of the region to decrease in economic activities and the capacity of countries in the region to adapt to the climate changes that do occur.

References

Anderson, D. (2006). *Costs and Finance of Abating Carbon Emissions in the Energy Sector.* Supporting Documents
for Stern Review, HM Treasury, London, UK.

Barrios, Salvador; Luisito Bertinelli & Eric Strobl (2010) Trends in Rainfall and Economic Growth in Africa: A
Neglected Cause of the African Growth Tragedy *The Review of Economics and Statistics* 92(2): 350-366.

Bernauer, T. A Kalbhenn, V Koubi, and Ruoff G (2011) Climate Change, Economic Growth, and Conflict, Institute
for Environmental Decisions (IED) and Oeschger Institute for Climate Change Research

CSIRO. (2006). Climate Change Scenarios for Initial Assessment of Risk in Accordance with Risk Management
Guidance. CSIRO Marine and Atmospheric Research.

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler and J. Yan (2007). The impact of sea level rise on developing
countries: a comparative analysis. *World Bank Policy Research Working Papers* Available at http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2007/02/09/000016406_20070209 161430/Rendered/PDF/wps4136.pdf.

Dell, Melissa; Benjamin F. Jones & Benjamin A. Olken (2008) *Climate change and economic growth:*

Evidence
from the last half century. Manuscript. Massachusetts: MIT.

Deschenes, Oliver & Michael Greenstone (2007) The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather. *American Economic Review* 97(2): 354-385.

Hurd, B., J. Callaway, J. Smith, and P. Kirshen. 1999. "Economic Effects of Climate Change on US Water
Resources." In R. Mendelsohn and J. Neumann, eds., *The Impact of Climate Change on the United States Economy.* Cambridge, UK: Cambridge University Press.

IPCC. (2007a). "Climate Change 2007: Impacts, Adaptation and Vulnerability." Contribution
of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge: Cambridge University Press.

IPCC (2007b). *Climate Change 2007: Mitigation.* Intergovernmental Panel on Climate Change. Cambridge, UK:
Cambridge University Press.

Karlsson, J., Jansson, M., Jonsson, A. (2007). Respiration of allochthonous organic carbon in unproductive forest
lakes determined by the Keeling plot method. *Limnol. Oceanogr*., 52(2), 603–608.

Kurukulasuriya, P., and R. Mendelsohn. (2008a). "A Ricardian Analysis of the Impact of Climate Change on
African Cropland." *African Journal Agriculture and Resource Economics* 2: 1–23.

Kurukulasuriya, P., and R. Mendelsohn. (2008b). "Modeling Endogenous Irrigation: The Impact of Climate Change
on Farmers in Africa." Policy Research Working Paper 4278. World Bank, Washington, DC.

Kurukulasuriya, P., and R. Mendelsohn. (2008c). "Crop Switching as an Adaptation Strategy to Climate Change."
African Journal Agriculture and Resource Economics 2: 105–126.

Lund, J., T. Zhu, S. Tunaka, and M. Jenkins. (2006). "Water Resource Impacts." In J. Smith and R. Mendelsohn,
eds., *The Impact of Climate Change on Regional Systems: A Comprehensive Analysis of California.* Northampton, MA: Edward Elgar Publishing.

Mansur, E., R. Mendelsohn, and W. Morrison. (2008). "A Discrete Continuous Model of Energy: Measuring
Climate Change Impacts on Energy." *Journal of Environmental Economics and Management* 55: 175–193.

Mendelsohn R. (2009) Climate Change and Economic Growth: Washington, the International Bank for
Reconstruction and Development / The World Bank. Working paper No. 60, Commission on Growth and Development

Mendelsohn, R., A. Dinar and L. Williams (2006) The distributional impact of climate change on rich and poor
countries. *Environment and Development Economics* 11: 159-178.

Mendelsohn, R. O., M.E. Schlesinger and L. J. Williams (2000) Comparing Impacts across Climate Models,
Integrated Assessment 1: 37-48.

Mendelsohn, R., and L. Williams. (2004). "Comparing Forecasts of the Global Impacts of Climate Change."
Mitigation and Adaptation Strategies for Global Change 9: 315–333.

Mendelsohn, R. (2007). "Dynamic Forecasts of the Sectoral Impacts of Climate Change." In M. Schlesinger, H
Kheshgi, J. Smith, F. de la Chesnaye, J. Reilly, T. Wilson, and C. Kolstad, eds., *Human-Induced Climate Change: An Interdisciplinary Assessment.* Cambridge, UK: Cambridge University Press.

Mendelsohn, R., W. Nordhaus, and D. Shaw. (1994). "Measuring the Impact of Global Warming on Agriculture."
American Economic Review 84: 753–771.

Miguel, Edward; Shanker Satyanath & Ernest Sergenti (2004) Economic shocks and civil conflict: An instrumental
variables approach. *Journal of Political Economy* 112(4): 725-753.

Neumann, J., and N. Livesay. 2001. "Coastal Structures: Dynamic Economic Modeling." In R. Mendelsohn, ed.,
Global Warming and the American Economy: A Regional Analysis. England: Edward Elgar Publishing.

Ng, W., and R. Mendelsohn. (2005). "The Impact of Sea Level Rise on Singapore." *Environment and Development*
Economics 10: 201–215.

Ng, W., and R. Mendelsohn. (2006). "The Impact of Sea‐Level Rise on Non‐Market Lands in Singapore." *Ambio*
35: 289–296.

Nicholls, R. J. (2004). "Coastal Flooding and Wetland Loss in the 21st Century: Changes under the SRES Climate
and Socio‐Economic Scenarios." *Global Environmental Change* 14: 69–86.

Nordhaus, W. D. (2008). *A Question of Balance: Economic Modeling of Global Warming*. New Haven: Yale Press.

Nordhaus, W. D. (1992). "An Optimal Transition Path for Controlling Greenhouse Gases." *Science* 258: 1315–1319.

Nordhaus, W. D (2007). "Critical Assumptions in the Stern Review on Climate Change." *Science* 317: 201–202.

Nordhaus, W. D. and J. Boyer (1999) Roll the Dice Again: Economic Models of Global Warming, Yale University
Available at http://www.econ.yale.edu/~nordhaus/homepage/web%20pref%20102599.PDF.

Nordhaus, W. D. and Z. Yang (1996) RICE: A Regional Dynamic General Equilibrium Model of Optimal Climate

Change Policy *American Economic Review* 86(4): 741-765.

Nordhaus, W. D. (2006) The Stern Review on the Economics of Climate Change Available at http://nordhaus.econ.yale.edu/SternReviewD2.pdf.

Nordhaus, William & Joseph Boyer (2000). *Warming the World: The Economics of Greenhouse Effect*. Cambridge,
MA: MIT Press.

Pearce, D., W. Cline, A. Achanta, S. Fankhauser, R. Pachauri, R. Tol, and P. Vellinga. (1996). "The Social Cost of
Climate Change: Greenhouse Damage and the Benefits of Control." In *Climate Change 1995: Economic and Social Dimensions of Climate Change*. Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Reid, H. (2005) 'Africa: a crucible for climate change and poverty' in T. Bigg and D.Satterthwaite (eds) (2005) *How*
to Make Poverty History: the Central Role of Local Organisations in meeting the MDGs. IIED, London. pp 157-175.

Reid H, L. Sahlén, J. Stage and MacGregor J. (2007), The economic impact of climate change in Namibia: How
climate change will affect the contribution of Namibia's natural resources to its economy. Discussion paper 07-02. London. International Institute for Environment and Development (IIED).

Smith, J., and D. Tirpak. (1989). *Potential Effects of Global Climate Change on the United States*. Washington, DC:
US Environmental Protection Agency.

Sokona, Y. and F. Denton (2001) 'Climate change impacts: can Africa cope with the challenges?' *Climate Policy* 1:
117– 123.

Tol, R. S. J. (2006) The Stern Review of the Economics of Climate Change: A Comment.
Energy and Environment 17 (6): 977-981.

Stern, N. (2006) Stern Review on the Economics of Climate Change. October 2006. Crown copyright 2006. Available at http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm.

Tol, R. (2002a). "New Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates."
Environmental and Resource Economics 21: 47–73.

Tol, R. (2002b). New Estimates of the Damage Costs of Climate Change, Part II: Dynamic Estimates,
Environmental and Resource Economics 21(1): 135-160.

Simms, A. and H. Reid (2005) *Africa – Up in smoke?* The second report from the Working Group on Climate
Change and Development. New Economics Foundation, London.

Sterner, T. and U.M. Persson (2007) An even Sterner Review – Introducing Relative Price into the Discounting

Debate *work in progress* Available at http://www.hgu.gu.se/files/nationalekonomi/personal/thomas%20sterner/b88.pdf.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review.* Cambridge: Cambridge University Press.

Yohe, G., R. S. J. Tol and D. Murphy (2007). On Setting Near-term Climate Policy while Dust Begins to Settle: The Legacy of the Stern Review. *Energy and Environment*, forthcoming Available at http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working papers/sternenergyenvironment2.pdf.

Weber, M. and G. Hauer (2003) A Regional Analysis of Climate Change Impacts on Canadian Agriculture *Canadian Public Policy* 29(2): 169-180.

Weitzman, M. (2007). The Role of Uncertainty in the Economics of Catastrophic Climate Change Available at http://www.economics.harvard.edu/faculty/Weitzman/papers/Catastrophe.pdf.

Winters, P., R. Murgai, E. Sadoulet, A. de Janvry and G. Frisvold (1998) Economic Impacts of Climate Change on Developing Countries. *Environment and Resource Economics* 12:1-24.

World Bank (2000) *Can Africa Claim the 21st Century?* World Bank, Washington D.C.

Weyant, J., and J. Hill. (1999). "Introduction and Overview." *The Energy Journal* (Special Issue: The Costs of the Kyoto Protocol): p. xliv.

Note:

Table 1. Climate change and economic growth

	Fixed effect estimation		Random effect estimation		Maximum likelihood estimation	
	n	Standard error	n	Standard error	N	Standard error
Constant	7.231251	.295599	7.580685	.1027728	7.581526	.0997437
Log of CO_2	.4062825	.3225992	.7880071	.062269	.7889251	.0605965
R^2	0.8221		0.8221			
F-test	1.59					
(p- value)	0.2162					
Wald-Chi(p-value)			160.15*	0.000		
LR Chi-bar sq (p- value)					163.34*	0.0000

Notes: * indicate statistical significance at the 5 per cent level