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THE ROLE OF TECHNOLOGY TRANSFER AND INNOVATION IN ADDRESSING PROBLEMS OF CLIMATIC CHANGE TO ENHANCING ECONOMIC DEVELOPMENT IN GLOBALIZING AFRICA

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ABSTRACT

Climate change poses daunting challenges to the future of humanities. Technology transfer and innovation are the effective and comprehensive approach for dealing with climate change issues. International cooperation on greenhouse gas mitigation and adaptation of climate change all involve in transfers of mitigated technologies or dissemination of knowledge on climate change. Technology transfer and innovation are inseparable component of any policy response of GHG mitigation and adaptation to climate change. In this paper, we delineate the scope of technology transfer and innovation as a routine way of combating this global challenge (climate change); concisely survey the literature regarding climatic change impact, technology transfer and innovation issues and ways of mitigating them to enhancing climatic friendly environment that can boost economic development in globalizing Africa. Thus, this paper concluded that for the pursuit of, technology transfer and innovation (TTAI) to contribute to global climatic change mitigation goals and address Africa's economic development needs, it is necessary to broaden the framing of and financial mechanisms for (TTAI) projects to include the complex and systemic relationships amongst the governmental, educational, social, political, economic and cultural dimensions of technical capabilities and knowledge circulation within and between countries. This will enhance socio-technological and innovative transitions towards mitigating climatic change impact to enhancing economic development pathways in Africa.

Keywords: Climatic Change, Technology Transfer, Innovation, African Economy.

INTRODUCTION

Climate change is the change in the average weather conditions in the atmosphere over a considerable length of time. It is attributed to natural events and anthropogenic activities on the lithosphere and hydrosphere that alter the atmospheric composition and variability in comparatively recent time periods (Henderson-Sellers, 1991). Climate change is a persevering challenge faced by entire humanities in the 21st century and beyond. Economic activities since the industrial revolution, mainly fossil fuel combustions and agriculture, have emitted huge amounts of greenhouse gases (GHGs) into the atmosphere causing depletion of the ozone layer. The anthropogenic GHG emission is the main source for measureable atmospheric temperature increases, global warming and other atmospheric contaminations over the present and the past decades (IPCC, 2007). Economists predict that global GHG emissions will keep increasing in the future, which will lead to further temperature increase, global warming increase, etc in the atmosphere. The climate that human beings have been used to for centuries will change drastically (IPCC, 2007).

Climate change has become a topical global policy subject and the empirical evidences on its impacts on less developed countries and global sustainability are now compelling. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) confirmed earlier conclusions by some researchers that no country and no region of the world will be unaffected, and in many countries the consequences for all human activities will be profound unless action is taken urgently to reduce GHG emissions. According to the IPCC (2007), the GHG concentration in the atmosphere would need to stay below the level of 450 parts per million (ppm) in order to prevent average global temperatures from rising by more than 2^0C above pre-industrial levels. This is widely considered the maximum temperature increase to avoid irreversible damage to global climate and ecosystems (IPCC, 2007). The latest scientific knowledge on climate change indicates that the world is on a GHG emissions trajectory which is worse than the IPCC's worst-case situation, and that there is a risk of severe disruption of the climate system if urgent action is not taken to reduce CO_2 emissions at the global scale. In addition to the GHG emission and climate change projections, the International Energy Agency's (IEA) *Energy Technology Perspectives 2008* report has estimated that the global energy demand will double from present levels by around 2030 (IEA, 2008). Forecasts suggest that energy use and resource consumption will grow at 1.2% in industrialized countries and 2.4 - 3.2% annually through 2030 in developing countries (International Energy Outlook, 2006).

In the face of persistent and increasing climate change impacts, Africa, like other continents, is gradually taking part in the global effort to reduce global warming owing to greenhouse gas (GHG) emissions and build her adaptive capacity, while also seeking alternative pathways for sustained economic growth. The Intergovernmental Panel on Climate Change reports (IPCC 2000; 2007 and 2012) conclude that any stabilization of GHG concentrations is not possible without spurring technological innovation and transferring new technologies and practices within countries and across national borders. Furthermore, as suggested in United Nations Framework Convention on Climate Change (UNFCCC) facilitated conferences of parties, climate change technology transfer (CCTT) can provide an avenue for developing a sustainable energy framework and thus, promote green growth strategies that allow for emissions cut and sustainable economic development simultaneously. The UNFCCC has therefore established legal obligations, frameworks and mechanisms for achieving climate resilient technology transfer and innovation. Many perceived effective transfer and diffusion of climate-friendly technologies developed from one country to another country as one of the proactive responses to the complex challenges of climate change (IPCC, 2000; 2007).

Studies have also shown that the transfer of efficient renewable energy systems and technologies – such as photovoltaic systems, solar thermal systems, or solar powered devices – can reduce the contamination of upward atmospheric pressure on fragile ecosystems, contribute towards better air quality and also give a chance to thousands of lower income households to get access to modern energy and improve their lives (Ockwell, *et al.*, 2008; Ighodalo, 2011). Most studies confirm the benefits of and the greater need for transferring and disseminating technologies to improve industries' competitiveness and grasp new opportunities for fostering economic growth in the developing world (Schnepp, *et al.*, 1990). Therefore, in this paper, we survey the role of technology transfer and innovation in the context of mitigating the impact of climate change on humanity as a means of achieving

economic development for globalizing Africa while emphasis are laid mostly on Nigeria as one of the African countries .

CAUSES OF CLIMATE CHANGE

Climatic change has been attributed to natural and artificial causes. The natural causes involve the interaction of our naturally occurring environmental agents while artificial causes result from the activities of man in our environment. For example, in Nigeria, in densely populated rural regions, there is greater competition for natural resources including agricultural and grazing lands, water and mineral resources, land tenure/fragmentation and shorter lengths of fallow period. In turn, these enhance deforestation for fuel wood collection and construction, accelerate soil erosion and expose fragile arable land to desertification.

In the urban centers, management of generated wastes (most of which are of non-biodegradable) road traffic effects and industrial activities are the main contributors to climate change. They result in hazards especially floods and increased concentration of GHGs.

Experience has shown that in the urban cities in Nigeria, and many other countries in Africa, oil and gas production is a major contributor to the Gross Domestic Product (GDP), the sector is a major contributor to GHGs emissions, global warming and climate change through clearing of natural ecosystem areas for production facilities, flaring of associated gases and high reliance on pollution-enhanced road transportation that use leaded fuels.

Air quality degradation, though least documented in some of the African countries is mostly localized and low compared with developed countries. Highest values are around urban centers and areas of oil exploration. For instance, resent investigation has shown that in Nigeria, Lagos has vehicular density of over 222 vehicles/km, and this has resulted in the air pollution load of about 51,800 metric tonnes and the major emissions include Sulphur dioxide (37.6%), Nitrogen oxides (31.5%) and Particulates (26.5%) (Soneye, 2012a & 2012b). Additionally, it is estimated that there are at least 5 million electricity generating sets of 5kvA and above in Nigeria. It is not strange to have a single house with 16 flats each having at least one generator each which has contributed immensely to the ozone layer deletion Soneye, 2012a & 2012b). These causes of climatic change in Nigeria for instance are shown in figure 1-6 below.

Fig 1: Industrial Emission in Niger Delta

Fig 3: Bush Burning in Benue State

Fig 2: Oil Degradation in Niger Delta

Fig 4: Oil Spillage in Niger Delta

Fig 5: Gas Flaring in Niger Delta

Fig 6: Transportation System in Lagos

The detrimental impacts of climate change have long-lasting, and sometimes have irreversible, consequences. To alleviate these impacts, international cooperation on technology transfer and innovation that will come out with a shared knowledge that will bring about reduction in the emission GHG is urgently called for. The United Nations framework Convention on Climate Change (UNFCCC), established in 1992, has been the grand institutional setting for potential international cooperation on climate change. Technology

transfers and innovation as the means of international cooperation and concrete approach of GHG mitigation have been at the center of policy debates and on the negotiation table.

International community has recognized the vital importance of technology transfer and innovation in coping with the problem of climate change. Without technology and innovation transfers, "it may be difficult to achieve emission reduction at a significant scale." (IPCC, 2007). Technology and innovation transfer should be a key component of any effective GHG mitigation strategies. Therefore, comprehensive studies of technology transfer and innovation issues are crucial to GHG mitigation policy designs and implementations. Transfer of environmentally sound technologies (EST) from developed countries to developing countries plays a key role in mitigation and adaptation in climate change. Technology diffusions among developed countries also enhance the effectiveness of GHG mitigation efforts.

TECHNOLOGY TRANSFER

The concept of technology transfer (TT) can be very broad. Quoting the definition of technology transfer from IPCC (2000); "technology transfer", is a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/education institutions". Nevertheless, technology transfer (TT), may convey varied connotations by scholars or decision makers under different contexts.

The first description of technology transfer in the literature conceived it as the moving of innovative technologies, new technical equipment, resources, practices and other specific skills from one setting (technology providers) to another (technology recipients/users) with a view to accelerating technology penetration (Mansfield, 1961; Blackman *et al.*, 1973; Mansfield, 1975). But in the year 2001, Rogers *et al.*, later proposed a non-exhaustive list of technology transfer mechanisms, which he conceived to be divided into two groups;

Group 1 Include:

a. ***Foreign Direct Investments (FDI) Mechanism*** characterized by; Vehicles for transmitting technology, technical know-how or technology-intensive products internationally through joint-ventures, wholly owned subsidiaries or spin-offs companies.

b. ***Licensing Agreements Mechanism*** *characterized by* Legal contractual rights for commercial and non-commercial users of developed intellectual property rights (patents, copyrights, trademarks, utility models, etc.) and other technological assets.

c. ***Grants and Cooperative Agreements*** characterized by Contracts allowing different entities (industry, non-governmental organizations, academia, public institutions, etc.) to collaborate with one another for the purpose of joint research and development (R&D) activities.

Group 2 Include:

a. ***Publications*** characterized by Open literature (books, articles, academic journals, magazines, etc.) and trade literature to transmit and share knowledge.

b. ***Cross-border Movements of Personnel*** characterized by Site visits, personnel exchanges and labour mobility programs, migration, etc.

c. ***Public Meetings*** characterized by conferences, seminars, workshops, symposiums, and other public forums. These mechanisms describe channels of knowledge flows and bilateral trade between technology developers and technology users, and among countries (Rogers et al., 2001).

INNOVATION

Innovation is widely recognized as essential condition for business success ensuring growth, sustainability and competitiveness. Innovation is a very broad concept and involves many different stakeholders varying from governments and scientists to business executives, marketing specialists and consumers. The diversity of the involved parties leads to different perspectives to innovation, thus resulting in different understanding of the concept. From the very general point of view innovation can be understood as a process from idea generation to commercialization – bringing the idea or invention to the market as a new product, process or service through the phases of idea generation, research and development, product development, marketing and selling a new product or service. The idea becomes an invention, when it is converted into a tangible new relic. The inventions are necessary seed for innovations, but the inventions do not inevitably lead to the innovation. Innovation is mostly regarded as the commercial and practical application of ideas or inventions (Trott, 2008, Varjonen, 2006).

Innovations are classified by the type, the degree of novelty and the nature (Terziovski, 2007, Tidd, *et al*., 1998). Four types of innovation are distinguished: product or service innovations, process innovations, marketing innovations and organizational innovations together with three degrees of novelty: new to the firm, new to the market and new to the world (OECD. 2005). There are also three types of innovation nature defined: incremental, radical, and disruptive (Terziovski, 2007). Types of innovation, degree of novelty and innovation nature define the three dimensions of innovation space.

In general, innovation studies focus on the flows of technology and knowledge among people and organizations. At national level for example, innovation and technology development are seen as the result of a complex set of interactions among agents producing, distributing and applying different types of knowledge. Literature suggests that the innovative performance of a country greatly depends on the particular arrangement of these agents within the collective knowledge system and the technologies they use (Etzkowitz and Leydesdorff, 2000). These agents are primarily private enterprises, universities, public research institutes, and the people among them.

Due to the increasing role of innovation as a strategic driver of economic development in nations, the study and better understanding of the principles governing knowledge and technology flows in innovations systems, acquires greater relevance, notably for strategic making of policies. This observation is even more relevant in the context of knowledge-based economies and emerging views on innovation such as the case of innovation as an open system or as eco-system. (Etzkowitz and Leydesdorff, 2000)

TECHNOLOGY TRANSFER AND INNOVATION CHANNELS

Technology transfer and innovation channels are the medium between particular participants in the process. They include ways of gaining the technology (e.g. buying, lending) and other important factors related to the process (e.g. flow of people, documentation, products, and capital).Technology transfer is conducted through different channels and different entities. Depending on the means of creating and gaining of the technology its transfer can be considered either internal or external. Internal technology transfer is conducted mostly inside a single entity or its affiliates. This entity acts both as creator / innovator and user. The scope of internal process is limited by internal R&D resources and implementation capabilities. External technology transfer relies on external technology resources usually not related to buyer. The scale of advancement in technology transfer depends on the advancement of R&D resources and the capabilities for technology implementation in the production process of the transferee (Blomstrom, 1992).

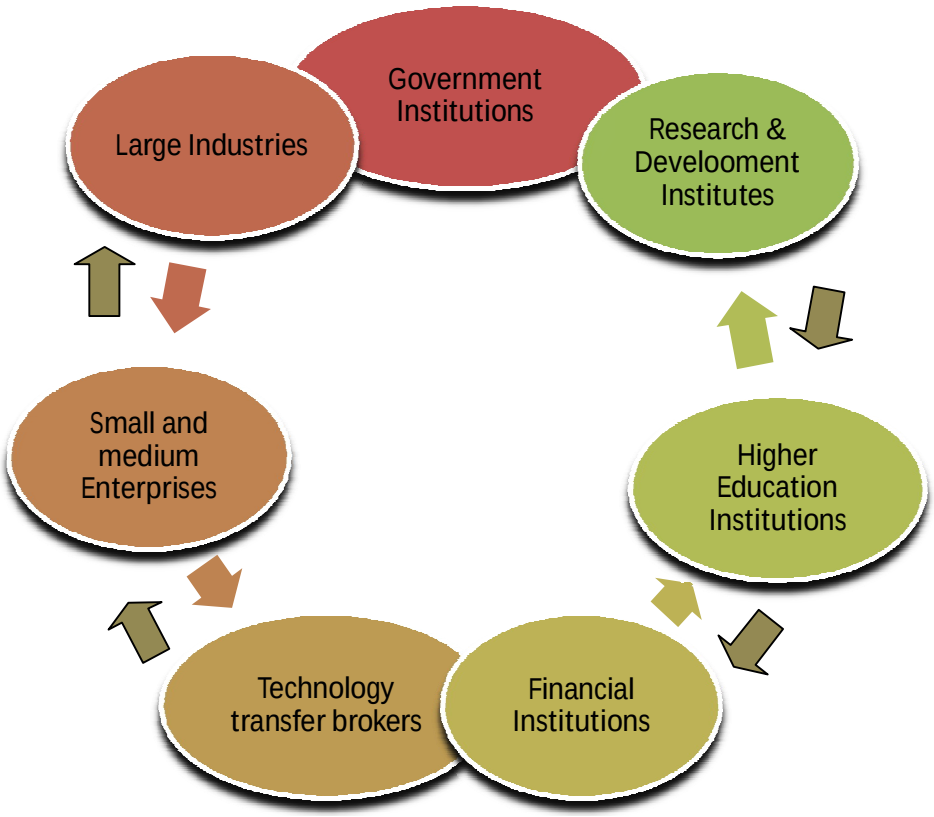

Fig 7: Technology Transfer and Innovation Channel Participants

In this context of technology transfer and innovation channels, they consist of cyclic interrelationship or cooperation as in fig 7 between different contributing sectors and actors of technologies to enhance planning, development, financing, deployment and diffusion, so as to achieve their common goal of sustaining climatic friendly environment.

NEGATIVE IMPACTS OF CLIMATIC CHANGE

In the past decades and present, research has shown that climate change generates human discomforts, adverse socio-economic impacts and socio-political crisis with untold calamities

and suffering both in the urban and rural areas (Soneye, 2004). Increasing population in human and natural activities in different parts of the continent has made them more vulnerable to natural and human-influenced changes in climate and environment.

Evidence from a panel of 136 countries over the period 1950-2003, (Dell, Jones, and Olken 2012) find three primary results from their study. First, higher temperatures substantially reduce economic growth in poor countries. For instance, a 1^0celsius (1^0C) rise in temperature in a given year reduces economic growth by 1.3 percentage points on average. Second, higher temperatures appear to reduce growth rates, not just the level of output. Third, higher temperatures have wide ranging effects, reducing agricultural output, industrial output, and political stability. Bernauer, *et al.,* (2010) using global data for 1950-2004, observe that the impact of climate change on economic growth is not robust to changes in climate change indicators and samples.

Frankhauser and Tol (2005) provide theoretical and empirical investigations on the link between climate change and economic growth using a simple climate-economy simulation model. They argue that the capital accumulation effect is important, especially if technological change is endogenous, and may be larger than the direct impact of climate change. The savings effect is less pronounced. The dynamic effects are more important, relative to the direct effects. They conclude that in the long run, for high direct impacts, climate change may indeed reverse economic growth and per capita income may fall. For global warming of 3^0C, the direct damages to the economy are estimated to at least 15 percent of Gross Domestic Product (GDP).

Higher growing temperature can significantly affect agricultural productivity, farm income and food security. The effect differs across temperate and tropical areas. In mid and high latitudes, the suitability and productivity of crops are projected to increase and extend northwards while the opposite holds for most countries in tropical regions (Gornall *et al.*, 2010). They find that a 2^0C rise in temperature in mid and high latitudes could increase wheat production by about 10 percent while in low latitude regions; it could reduce by the same amount. Their projection, taking the effect of technology into account, found that rising temperature in Russia Federation could increase wheat yield by between 37 and 101 percent by 2050s.

In addition, Salvador, et al (2004), found the effect of rising temperature on agriculture to be more severe in Sub-Saharan Africa than other developing countries. Results from simulation exercises suggest that if the climatic conditions (rainfall and temperatures) had remained at their pre 1960s level, the gap of agricultural production between Sub-Saharan Africa and other developing countries at the end of the 20th century would have been only 32 per cent of the current deficit. Evidence from Ayinde *et al.,* (2011), using econometric analysis on Nigeria, (1980-2005), reveals that temperature change generated negative effect while rainfall change exerted positive effect on agricultural productivity.

The Fourth Assessment Report of the IPCC provides some illumination results about the impact of climate change on African development. For instance, projected reductions in yields in some countries could be as much as 50% by 2020, and crop net revenues could fall by as much as 90% by 2100, with small-farm holders being the most affected. It will also aggravate the water stress currently faced by some countries - about 25% of Africa's

population (about 200 million people) currently experience high water stress. The population at risk of increased water stress in Africa is projected to be between 350-600 million by 2050 while between 25 and 40 percent of mammal species in national parks in sub-Saharan Africa will become endangered (Boko, *et al.*, 2007).

Fig 8: Contaminated Water in Niger Delta

Fig 9a: Flooded Homes in Makurdi Benue State

Fig 9b: Flooded Homes in Makurdi Benue State

Fig 9c: Flooded homes in Makurdi Benue State

Fig 10: Flood Ravaged Police Station in Lagos

Fig 11: Flood Displaced Home in Bayelsa

However, some of the most prevailing impacts of climatic change as captured in some parts of Nigeria which are also prevalent in most of other African countries are shown in the above figures 8-11. These impacts of climate changes include contamination of water bodies which

reduces access to portable water especially in the drier North, (Fig 8), floods from concentrated rains and releases of uncontrollable waters in dams upstream (Fig 9 a, b & c) and (Fig 10 and 11), dwindling food production, exacerbated sea level changes, saltwater intrusion and loss of biodiversities among other .

Recent human-induced disasters from fire outbreaks, religious and communal clashes in different countries of Africa are traced to natural resources challenges being created by climate change (Fasona and Omojola, 2005). Interests are on the impacts and vulnerability on the populace and their environments. They focus on population pressure and dislocations, ill-health and infrastructural deterioration cannot be overemphasized (Ehwarieme and Cocodia, 2011).

ROLES OF TECHNOLOGY TRANSFER AND INNOVATION IN ENHANCING CLIMATIC FRIENDLY ENVIRONMENT

Climate change is one of the most complexes, multifaceted and serious threats the world faces today. “The response to this threat is fundamentally linked to pressing concerns of sustainable development and global fairness; of economy, poverty reduction and society; and of the world we want to hand down to our children” (UN Secretary General Ban Ki-moon).
The adaptation of the low atmospheric -carbon emission technology transfer can be found in the mitigation of long-term costs associated with climate change. Investments in climate resilient technologies in the most sensitive sectors of the African economy (agriculture, energy, industry, etc.) will not only reduce the impact of climatic change, but will majorly boost the African economies now; it will also reduce mitigation costs later. As aptly argued by Kypreos and Turton (2011), subsidized transfer of technology and know-how, when appropriately designed, will contribute to increasing welfare because of induced technological learning and capacities that stem from the deployment of new technologies and hence, generate potential to lower costs of achieving mitigation and adaptation objectives. Therefore, the following table (table 1) illustrates some of the major roles of some selected technology sectors in climatic change mitigation.

Table 1: Some Climate Change Mitigation Potential Technologies in the Developing World

Technology sector	Developing world Mitigation potential (2030, per annum)	Responsive technology examples	Methods of encouragement	International Technology transfer and investment special issues
Renewable electricity sources	0.63$GtCO_2$	Wind Photovoltaic	Private market Subsidy Regulation	Transfer of product or of industry
Carbon-based energy production	0.39 $GtCO_2$	Carbon capture and storage	Regulation Research support	Public R&D
Biofuels	0.46$GtCO_2$	Ethanol	Private market Regulation Subsidy	Market competition
Industrial efficiency	0.16$GtCO_2$ (steel alone)	Steel and cement production	Regulation	Market competition
Consumer conservation	1.50$GtCO_2$	More efficient appliances	Regulation Subsidy	Willingness to subsidize consumer
Nuclear power	0.72$GtCO_2$	Nuclear facilities	Subsidy Research support	International security, Commercial competition

(**Source**: EEDP 08/02)

There are many different technologies involved in climatic change mitigation and they differ from sector to sector. For the sake of prevailing causes of climatic change in Africa, a selection is chosen in this paper; the examples considered are summarized in Table 1, with the Vision of 2030 mitigation potential in the developing world shown, and based on the IPCC Mitigation analysis. Each sector is unique in the way the technology fits into the economy and is regulated or subsidized to encourage the reduction of emissions of CO_2 in the atmosphere. Each sector therefore brings significantly different technological development, transfer, and investment concerns.

BARRIERS OF TECHNOLOGY TRANSFER AND INNOVATION TO ENHANCING CLIMATIC FRIENDLY ENVIRONMENT

Limitation in the Existing Models of CCTTAI in African

Assessments show that the prevailing mechanisms for climatic change technology transfer and innovation (CCTTAI) to Africa have been predominantly designed on the basis of the linear models of innovation diffusion, with more focus on transferring climate resilient technologies and innovations from the Global North (including US) to the Global South (including Africa). This top-down methodology of North-South cooperation has often resulted in mixed outcomes and also raised various contentions amongst parties. Also, linear models of technology transfer do not, in practice, allow for equal partnerships and participatory technology needs assessments (TNAs) for sustainable socio-technological transitions in Africa. Though the UNFCCC emphasises the need for equal partnerships and country driven TNAs, this has not been fully implemented in the African case studies reviewed (Brewer, 2004). Existing TNA projects still give the experts (technology producers and other consultants) central roles in the sector prioritization and development of the technology selection criteria. Studies on the continent have shown that different actors in the innovation systems hardly cooperate with each other due to multiple limiting factors (Urama

et al., 2010). This has led to poor socialisation of climate change technologies in the socio-cultural and political economy of the recipient countries, resulting in low success and sustainability rates.

Economic Barriers

Most studies show that the initial investment costs of clean technologies are currently higher than existing carbon-intensive alternatives. For example, IPCC, (2012) shows that equal costs of renewable energy technologies are currently higher than fossil fuel alternatives. From a neo-classical economic policy perspective, many of the current low carbon technology alternatives are not yet competitive with carbon-intensive options and so market demand for the former tends to be weak or marginal (Ockwell and Mallet, 2012). Besides, investments in some of these technologies are likely to be risky at their early stages of commercialization (Karakosta *et al.,* 2010). This is often due to the lack of information from both technology providers and recipients on (investment opportunities, advantages of the technology, local needs and technological capabilities of the recipients, transaction costs, associated risks, etc.), but also unstable markets and policy environments in most African countries. The combined effects of inherent market failures and information asymmetry, high import tariffs and high initial investment risk in many African countries also contribute to the low rates of adoption of climate change-related technologies in Africa.

Governance-Related Barriers

Governance related barriers to achieving CCTT in Africa include existence of ineffective policy and regulatory capacity, such as enforcing fair and equitable power of purchase agreements, market entry, and Intellectual Property Rights (IPR) regimes. Most African governments lack the institutional and policy frameworks required for the development, regulation, mediation and use of CCTs. Muller (2010) observed that CCTT are not embedded in a broader policy framework of countries in the Global South, and this has resulted in institutions failing to utilize the inherent potentials of the technology, including available climate finances. In most cases, there is no existing climate policy to provide direction and frameworks for institutional operation in the development and use of CCTs thereby making it more difficult to engage with CCT developers. Thus, emphasizing the need for effective governance in Africa, the Mozambican President Armando Guebuza noted during the African Union Heads of States Summit in 2007;

"it must be made clear that without the commitment of the leadership; there can be no scientific and technological development on our continent" (Mutume, 2007).

International Trade Rules and Tariffs Structure Limitation CCTTAIs in Africa

Climate Change and international trade, investment and technology transfer issues have intersected in diverse institutional contexts and at several levels of governmental activities. Amongst the thorny issues include how to offset border measures that address international competitiveness and 'free rider' concerns in CCTTAI projects; trade tariffs and non-tariff barriers to investment and technology transfer of climate-friendly goods and services; streamlining programs that promote exports, foreign direct investments and technology transfers, especially to developing and emerging economies within international climate change technology cooperation agreements; managing subsidies for renewable energy and

energy efficiency goods and services; and carbon pricing and eco labelling of products, and managing intellectual property rights in CCTTAI projects.

Such tariff in African countries, include but not exclusive to the unilateral trade measures (UTMs) tariffs and nontariff trade barriers adopted by developed countries, which could be an arbitrary or discriminatory restriction on international trade practices (Choi, 2009). Border measures could adversely impact the overall export basket of African countries, and more particularly the export competitiveness of their energy-intensive sectors. In the complex process of transfer of technology, the role of IP protection—despite being only one of many influential factors—has proven particularly contentious (CTI, 2001). In all, the emerging consensus is that current IPR regimes do not work in favour of African countries who are not importers of technologies and products (Osuji, 2010).

Lack of Local Capacities to Implement and Use Transferred Technologies

Another barrier to optimizing CCTTAI benefits in Africa is the lack of technical capacity for R&D; development and deployment; and operations and management (O&M) support for CCTs (UNDP 2009). Africa's sustainable development will depend more and more on its capacity to find innovative solutions to its peculiar problems especially in the areas of food insecurity, health issues and environmental challenges. Having the required technical and institutional capacities to adopt and adapt, use and management of CCTs is a pre-requisite for successful application of the technology. There is high probability that proven CCTs transferred from North to South might not lead to the expected results due to lack of adequate capacity to adopt, adapt and use them. Technological capacity is positively correlated with education and hence in a knowledge economy, education (especially tertiary) is a significant driver to access the technological capability of a country. Unfortunately, the gross enrolment ratio (GER) in the tertiary level of education in High-income countries (HIC) is higher than in Africa.

Poor Implementation of National System of Innovation

The coordination and integration of STI programmes and activities into one single innovation system that brings actors from different ministries and agencies working together remains an illusion in many African countries. This is because of the weak or absence of a National Systems of Innovation (NSIs) in most African countries. Climatic change is a phenomenon that cuts across all facets of life and therefore demands a trans-disciplinary approach and equitable engagement of all participants in the NSIs in the development, deployment, adaptation and use of emerging CCTTAI.

Low Investments in Science, Technology and Innovation in Most Recipient African Countries

African leaders have pledged to devote more resources to the development of science and technology, an area deemed vital for economic development, yet long neglected and poorly funded in many countries. At a January 2007 summit of the continent's political body, the African Union, Heads of State urged all AU countries to allocate at least 1per cent of their gross domestic product to research and development by 2020 (Mutume, 2007) - an idea already recommended by UNESCO. As at 2010, available data suggest that only few countries had met this target (Urama, *et al.,* 2010).The low investment in R&D has consequently resulted in low scientific productivity in the form of patents, publication, and spin-off industries, etc.

WAYS OF ACHIEVING ENVIRONMENTALLY CLEAN TECHNOLOGY TRANSFER AND INNOVATION

The concept of adaptation should lead to the transfer of environmentally sound technologies. According to the *World Development Report 2010: Development and Climate Change*, ... a two-degree Celsius warming above pre-industrial levels could permanently reduce Africa's annual per capita consumption by four to five per cent....The report calls on industrialized countries, which have released most of the greenhouse gases, to lead the way in charting a new low-carbon economic path. In addition, the report calls for financial support to enable developing countries adapt to climate change and lay the foundation for low-carbon economies. On that ground, a proactive measures that can enhance innovative and technology diffusion should be adopted. Such measures include but not limited to;

Encouragement of Stakeholder Participation in TNAs at Country Levels

The first step toward a sustainable socio-technological transition will be to engage local expertise and practitioners in identifying the technology capacity gaps, needs and priorities. The spirit and principle of Total Nonstop Actions (TNAs) which have been the measure adopted by developed countries and requiring full engagement of all stakeholders in the identification of needs and priority sectors has not being fully adopted in Africa. Identifying lead experts to implement TNAs has often been a challenge in Africa. Engaging long standing institutions with pan-African mandates such as the African Technology Policy Studies Network (ATPS) and the Africa Climate Policy Centre (ACPC) could be helpful in ensuring broader engagement in TNA implementation in African countries**.**

Advancement in the Climatic Change Technology Transfer and Innovation Projects

This should include multilateral knowledge sharing amongst the global community to enhance the adaptive and resilience capacities of all actors in the Climatic Change Technology Transfer and Innovation (CCTTAI) chain. This will enhance the capacities of the least developing countries to evolve from global consumer of technologies and innovations for development to self-producers of technologies to meet local conditions. The history of innovation diffusion confirms that this form of socio-technological transitions is far more sustainable and effective than bilateral transfer of technologies to other African continents.

Capacity Building for African Governments and Technology Based Institutions in CCTTAI Projects

For CCTTAI projects to be sustainable, there is urgent need for institutional capacity building for technology gate keepers on the continent and also all the key actors in the national systems of innovation in Africa. Established experiences in technology diffusion studies show that capacity building of institutional segment in African countries is a key to successful diffusion of new technologies and innovations. In this regard, it is worth stating that there have been bilateral efforts between the U.S. government and a number of developing countries, among which are Egypt and the Southern African Development Community, to foster climate change technology transfer in the developing world through programs such as the Technology Cooperation Agreement Pilot Project (TCAPP) and the Climate Technology Partnership (CTP). Up-scaling such joint projects to reach other countries in the continent of Africa will be a positive step. These projects and programs can be implemented in partnership with academia, independent research organizations and laboratories with the African institutions and countries cost-sharing research within and

outside African countries that are more technology inclined to foster innovations and entrepreneurship culture in African countries.

Inclusion of CCTTAI in National Development Plans

African countries have not always given due attention to cooperation in the context of climate-related technology transfer. Consequently, most Global Environmental Facility (GEF) and CDM projects are not considered as part of the overall national development strategies. Embedding CCTTAI in national development policies and plans would go a long way to fostering national interest and effective implementation of CCTTAIs that will at the end foster climatic friendly environment in Africa.

CONCLUSION AND RECOMMENDATIONS

This work has actually stressed that climatic change is not only one country's affair; it is rather a global affair which needs urgent attention to mitigate the devastating impact caused by humanity. We are of the view that, for African to fully achieve their mission of economic development and globalization in this century and beyond, they should; this impact caused by climatic change has been traced to affect national development and the economy of such nation. Thus, a routine strategy (technology transfer and innovation) have proven positive towards achieving climatic friendly environment if adequately implemented view that:

- Include an incentive package to scale up technology development and transfer to developing country parties in order to promote access to affordable environmentally sound technologies *through* creation of additional value and crediting for participation in technology development, deployment, diffusion and transfer for greenhouse emissions reduction and enhanced resilience to impacts of climate change

- Incorporate an institutional mechanism and tools for supporting, supervising, monitoring and evaluating the effectiveness of the implementation of agreed actions on technology development and transfer;

- Provide for a compliance and enforcement organization for development and transfer of technologies linked to quantified emissions reduction and limitation commitments and increased resilience of communities and ecosystems to the impact of climate change

- Support capacity building and capacity development in developing countries for technology development, adoption, deployment, diffusion and transfer including, inter alia, support for national systems of innovation

- Ensure improved access to new and additional, adequate, predictable, appropriate, equitable and sustainable public-sector financial resources and investments to support mitigation and adaptation and technology development, transfer and technology cooperation

- Promote substantial private-sector participation, finance and investments in technologies for mitigation and adaptation

- Ensure protection of intellectual property rights that guarantees access to and use of technologies by avoiding over-protectionism

- Ensure access to technology information, including in particular the costs and performance of technologies

- Provide for international programme for joint or collaborative research, demonstration and early stage deployment of technologies

- Provide guidance on national/domestic government policies needed to, notably creating a higher level of long-term policy certainty s

- over future demands for low carbon technologies, upon which the private sector including the industry's decision makers can rely, and for private financing of technologies for adaptation.

- Pay specific attention to the technology needs of (a) major emerging and big economies, (b) emerging but small developing economies, and (c) least developed countries, and (d) small island developing states; among developing countries

- Promoting and providing direct incentives for technology programmes such as supporting international technology cooperative development networks, national policies/actions, certify credits for special and priority technology programmes, and managing long-term regulatory risk.

- Assist member countries to develop the necessary "pull" mechanisms or enabling environment (starting with power sector)

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