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Energy Consumption and Health Outcomes in Africa

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ABSTRACT

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We examine causal links between energy consumption and health indicators (Mortality rate under-5, life expectancy, greenhouse effect, and government expenditure per capita) for a sample of 16 African countries over the period 1971-2010 (according to availability of countries' data). We use the panel-data approach of Kónya (2006), which is based on SUR systems and Wald tests with country specific bootstrap critical values. Our results show that health and energy consumption are strongly linked in Africa. Unilateral causality is found from energy consumption to life expectancy and child under-5 mortality for Senegal, Morocco, Benin, DRC, Algeria, Egypt, and South Africa. At the same time, we found a bilateral causality between energy consumption and health indicators in Nigeria. In particular, our findings suggest that electricity consumption Granger causes health outcomes for several African countries.

JEL Classification: Q43, Q53, Q56

Keywords: energy consumption, electricity, health, Panel VAR

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1. *Introduction*

Economic growth in industrialized countries has historically gone hand-in-hand with increasing energy intensity [Reference]. This is also the case for developing countries where impacts of energy consumption and use on economic development and the progress are increasingly significant [reference]. Africa is following the same trend and the intensity of energy consumption is increasing rapidly with the economic growth in the last decade.

Africa is experiencing recent rapid economic development and an increasing demand on energy supply. The Continent presents mixed situation with large energy producing countries relying on oil and gas (mainly in North Africa); other countries largely relying on coal (South Africa); and Sub-Saharan Africa having strong dependence on biomass. The expected boom of the African population with an increase from 1 billion to 2.3 billion people by 2030 makes it necessary to consider the sustainability of energy use in order to mitigate environmental and public health damages.

Three main problems can be identified when discussing the energy-health nexus in Africa. Firstly, many African citizens have insufficient access to modern energy sources and largely rely on biomass. This causes health problems due to indoor air pollution caused by the use of traditional fuels. In fact, a large majority of the population is facing problems with access to energy due to unavailability and unaffordability of modern energy sources. Energy poverty and insecurity are major components of poverty [Reference]. Secondly, increasing urbanization, in particular in big cities, seems to present serious negative effects on health when the populations in the new urban areas are lacking access to clean and affordable energy sources [reference]. The combustion of biomass and the coal in urban areas leads to high levels of indoor and outdoor air pollution. This air pollution is exacerbated by the use of "non-clean" technologies by industries and inefficient transports. Thirdly, global warming is modifying Africans life style with deep impact on their health. Global warming and the desertification of certain areas result in the depletion of some traditional energy sources like biomass.

Several papers reported positive effects of energy consumption on economic growth (Arouri et al. 2014, Adom, 2013), education (Ben Abdelkarim et al. 2014 b) and employment (Adom, 2014) in Africa. However, less is known about the effects of energy consumption on health in Africa. Researchers report balanced effects: while for some of them each further

increase in energy consumption produces ever-smaller health gains, others have shown that energy use engender indoor and outdoor pollutions with significant impacts on environment and public health. Pollutants, such as Inhalable Particulate Matter (PM), Methane, micro metal elements, and SO2 have been destroying the environment and affecting public health negatively. Respiratory infections caused by air pollution from energy incomplete combustion are the main threat to the health in developing countries. Wang (2010) reports that 43 millions people would die of respiratory infection each year. However, global studies showing the long-run effects are lacking.

The objective of this paper is to address this gap in knowledge by (i) proposing an analytical framework to discuss the health effect of energy and electricity consumption in Africa; (ii) empirically identifying how increased energy consumption (especially electricity) can improve health outcomes in Africa; and (iii) exploring direct causality between energy consumption, under-5 child mortality and life expectancy as well as indirect causality between energy consumption, greenhouse effect (air pollution) and government health expenditure. The analysis focuses on 16 African countries.

The first part of the paper discusses the positive and negative impacts of energy consumption on health. The second part presents the methodology, parameters, and data used. A policy discussion is engaged in the third section followed by recommendations.

2. Expected Health impacts of Energy use and electricity consumption

Energy and public health have not been analyzed together in a single framework until recently, and environment is usually looked as the media in the chain of energy, emission, environment, and human health. We propose in this section to identify the main health problems in Africa and to identify how provision of clean energy can improve Africa's health outcomes.

2.1. What are the main health problems due to insufficient energy consumption?

Energy consumption and electricity consumption have several direct and indirect impacts on health. This section summarizes the main effects and discusses the channels through which energy consumption (electricity consumption) can affect negatively or

positively a population's health. We restrict ourselves to the channels that are the most pertinent in the African context.

Indoor pollution due to use of biomass

Energy is essential for cooking and heating. It permits access to cooking and hot meals. Evidence on link between good nutrition in children and good health outcomes (also education outcomes) is well established. Lack of access to modern energy sources lead to the usage of biomass energy (mainly woods) as the principal source of energy. The World Health Organization (WHO) estimates that 3 billion people in the World are using Biomass for cooking (2006). While biomass permits access to hot meals and heating, the inefficient burning of solid fuels on an open fire or traditional stove indoors creates a dangerous cocktail to hundreds of pollutants, primarily carbon monoxide and small particles, but also nitrogen oxides, benzene, butadiene, formaldehyde, polyaromatic hydrocarbons and many other health-damaging chemicals. Where coal is used we can add to this list of pollutants sulfur, arsenic and fluorine. The problem of indoor air pollution still fail to mobilize the international community while the WHO estimates also that 4.3 million people a year die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels (WHO, 2014). Indeed, several diseases are associated with indoor pollution such as acute infections of the lower respiratory tract, chronic obstructive pulmonary disease, lung cancer, asthma, cataracts and tuberculosis. In 2002, in Sub-Saharan Africa 396 000 deaths were due to indoor smoke (WHO, 2006). In context of the contribution of energy technologies, Ezzati and Kammen (2002) studied the effect of indoor air pollution on the residents' health during the two years after advanced energy technologies were introduced. The result showed that stove efficiency innovation could significantly decrease mortality and acute respiratory infections in children.

The indoor pollution problem has a gender bias aspect since women and young girls in developing countries are particularly affected by the negative health outcomes of indoor air pollution (IAP) from the use of solid fuels. Since women are usually responsible for cooking while taking care of children, women and children are most exposed to IAP from the use of solid fuel and its subsequent health impacts. This activity has also an impact in matter of time spent by children and women in order to collect woods and biomass sources of energy. This time devoted to collecting woods and biomass sources of energy is taken from the time devoted to education or other productive activities. Young children living in households

exposed to biomass indoor pollution have a two to three time greater risk of developing an acute lower respiratory infection (ALRI) than others. They are more susceptible than adults to absorb pollutants, since their lungs are not fully developed until they reach their late teens. A study in rural Kenya found that the amount of pollution a child is exposed to correlates to the risk of developing pneumonia (Ezzati and Kammen, 2002).

Outdoor Pollution

Air pollution has several adverse health effects such as asthmatic, cardio-vascular and other related health outcomes. In spite of an increasing awareness about these effects and "better" legislated air pollution policies in many countries, recent studies estimate that 80% of the world's population continue to be exposed to ambient pollution that far exceeds the WHO recommended Air Quality Guideline (AQG) of 10mg/m3 for long-term PM2.5 concentration levels (particulate matter with aerodynamic diameter smaller than 2.5 mm) (Van Donkelaar et al., 2010; Rao et al., 2012; Brauer et al., 2012).

Moreover, the increasing urbanization of the African continent and the emergence of megacities like Cairo, Casablanca, Lagos, Kampala has been shown to be associated with air pollution and public health issues [Ref]. Inefficient means of transport, usage of "non-clean" technologies and inefficient ways of cooking have engendered important air pollution and concentration of PM. Estimates indicate that outdoor and household air pollution are globally among the leading causes of mortality and morbidity related outcomes in developing countries (Lim et al., 2012). Emissions from cooking stoves continue to be a major component of global anthropogenic particulate matter (e.g., (UNEP/WMO, 2011)) in particular in Africa and South Asia where emissions from cooking stoves are well over 50% of anthropogenic sources (Bond et al., 2004a, 2013).

Smith (2006) studied air pollution situation in China by referring to the theory of ''Total exposure assessment'', in which he reviewed the relationship between energy consumption and air pollution, introduced the exposure assessment method, and analyzed the impact of air pollution on public health. Kunzli et al. (2000) analyzed the contributions of air pollution to mortality and morbidity resulted from outdoor and traffic-related air pollution in Austria, France, and Switzerland based on the ''Epidemiology-based exposure–response functions''.

Climate change and energy efficiency related policies are additionally being

undertaken in many countries and these are likely to cause energy transformations that will impact air pollution and health related outcomes in the future. There is a growing body of research focusing on the public health and potential climate co-benefits of improving access to modern cooking fuels and stoves in developing countries (Bond et al., 2004b; Haines, 2007; Smith and Balakrishnan, 2009).

Cold related diseases due to lack of energy access

Living in cold homes has been linked to excess winter deaths, Chronic Obstructive Pulmonary Disease (COPD), and respiratory tract infections, as well as increased risk of heart attacks and strokes due to raised blood pressure (Marmot Review Team, 2011). The damp or mould that can accumulate in cold homes has been shown to affect allergic or respiratory conditions including asthma (Fisk et al., 2007) and, in general, stress, depression, and low levels of wellbeing have all been linked with cold or damp housing (Shortt and Rugkasa, 2007). Given the evidence linking cold housing to poor health, it could be assumed that energy efficiency measures should beneficially affect the health of householders. Consistent with this idea, household energy efficiency interventions have been shown to result in a diverse range of positive health impacts (Thomson et al., 2009, 2013), including children's respiratory health, weight and susceptibility to illness, the mental health of adults (Liddell and Morris, 2010), better self-reported health, and reduced respiratory symptoms and school absences due to asthma (PHIS, 2006).

Africa is generally associated with warm and several areas have extreme temperatures like deserts where the temperature is very high during the day and very low at night. Without access to energy there is no way of regulating the temperature and bodies are exposed to several dangers (skin cancer…).

There is also evidence that improved domestic space heating can reduce school absences and health service use for children with asthma (Preval et al., 2010). Given that financial strain may worsen both mental and physical health improving the energy efficiency of homes can also contribute to a better quality of life by reducing energy bills.

Child mortality and inefficient provision of energy

5.9 children aged under five years died in 2015 (http://www.who.int/gho/child_health/mortality/mortality_under_five_text/en/), primarily in

low income countries. The risk of a child under five dying is about 7 times higher than that of a child in the WHO European Region. . The leading cause among children aged 1-59 months is pneumonia (http://www.who.int/gho/child_health/mortality/causes/en/). Acute lower respiratory infections were responsible for 0.9 million deaths of children under 5 in 2015 (http://apps.who.int/gho/data/view.main.CM1002015WORLD-CH9?lang=en). New born and infants are often carried on their mother's back while she is cooking, or kept close to the warm hearth. Consequently, they spend many hours breathing polluted air during their first year of life when they are developing airways and their immature immune systems make them particularly vulnerable. More than half of deaths among children under 5 from acute lower respiratory infections are due to indoor air pollution from household solid fuels (WHO). These deaths are not equally distributed throughout the world: more than one third of the child deaths due to indoor smoke occur on the African Continent.

Thus, energy affects positively and negatively health. The sign of the total effect is not clear and needs to be discussed at continental level as well as over sub-regions. Improved energy services can reduce child mortality, improve maternal health, reduce the time and transport burden on women and young girls, and lessen the pressure on fragile ecosystems.

Availability of clinics, care centers and disincentive for doctors and nurses

Another important aspect of energy provision and especially electricity availability is the fact that those facilities are important for health care services. Without electricity most of basic medicine acts cannot be done. Provision of electricity makes it possible to use more sophisticated materials and to act at the nearest place of ill persons, avoiding for them long distance travel and transport which may complicate their initial injuries or diseases. Doctors and nurses are more motivated to access clinics and care centers where energy provision (especially electricity) is available. Lack of electricity is also a disincentive for doctors and nurses to live in those areas and can impact their absence at work. It is obvious that energy and electricity access decreases doctors and nurses absence. Modern energy provision also reduces child mortality, improves maternal health and combats HIV/AIDS, malaria and other diseases. Electricity-access strategies should target public facilities such as health clinics, which benefit the whole population in an area, so that they can provide essential services needed to improve life quality and generate income.

2.2. How can provision of modern energy sources improve population's Health?

Increasing the availability of energy affects directly the health of humans. We discuss in this section five channels through which access to modern energy can improve population's health.

Revenue generation of energy sector can be used for the health sector

Energy is a special service. Governments generally include several taxes in the energy market. Most of these taxes are settled in order to internalize the externalities of energy. By this mechanism, selling energy generates revenues that can be used to cover hospitals and care centers costs. In some cases, revenue generated from energy improves health services. For example, these revenues can serve to build health centers in rural areas. They can also serve to build medical schools or finance research centers or to strengthen other aspects of the health system including human resources for health and supply chains.

Better refrigeration of basic medicines

Lack of energy is also associated with lack of hygiene conditions and inability to conserve medicines. Sterilized supplies, clean water supply and refrigeration of essential medicines are impaired in health facilities without adequate electricity. Access to modern energy permits the households to buy refrigerators and to keep the medicines available for a long time. Lack of electricity implies also less efficiency in cold chains and distribution of medicines and vaccines. \

Energy consumption can also reduce child mortality

The WHO (2006) shows three main channels through which improvement of energy practices can reduce child mortality. Firstly, reducing indoor air pollution will prevent child morbidity and mortality from acute lower respiratory infections. Secondly, protecting the developing embryo from indoor air pollution can help avert stillbirth, perinatal mortality and low birth weight. Thirdly, getting rid and open fires and kerosene wick lamps in the home can prevent infants and toddlers being burned and scalded. At the same time refrigeration permits medicines conservation and better conservation of food. By this means several diseases can be avoided.

Energy consumption can improve maternal health

Better energy practices can improve maternal health through three channels. Firstly, curbing indoor air pollution will alleviate chronic respiratory problems among women. Secondly, a less polluted home can improve the health of mothers who spend time close to the fire after giving birth. Thirdly, a more accessible source of fuel can reduce women's labor burden and associated health risks such as prolapse due to carrying heavy loads. Lowering levels of indoor air pollution could help prevent tuberculosis cases. Moving up the energy ladder and using improved stoves can increase energy efficiency and decrease greenhouse gas emissions.

Electricity consumption permits access to ICT and to e-Health applications

While there is a consensus about the potential effects of ICT on health in Africa little is said about the access to and consumption of electricity and energy by ICT devices. The health related benefits from ICT are not possible without resolving issues related to energy access and consumption , in particular electricity. Alternative solutions, like electricity out of the grid or solar batteries are partially resolving the problem.

In this section we have seen that poor energy consumption has a negative impact on health outcomes. Increasing the provision of cleaner energy (especially electricity) can substantially improve health outcomes in Africa. Next section proposes the methodology used to identify the long-term relationship between energy consumption and health outcomes.

3. Methodology, data and econometric model

This paper contributes to the literature with a bootstrap panel analysis of causality relationships between energy consumption or electricity consumption and health for a sample of 16 African countries: Algeria, Benin, Cameroon, Democratic Republic of Congo, Egypt, Ethiopia, Ghana, Kenya, Morocco, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Tunisia and Zambia.

Three main reasons justify our sample. Firstly, the availability of data for all our variables. Secondly, the selected countries cover the heterogeneity of Africa since they cover all parts of Africa (South, North East, West and Central Africa). Thirdly, our sample contains the three types of African countries: Fragile States, Middle Oncome Countries and Low Income Countries. We will thus be able to test whether those countries have the same trends.

Data are annual over the period 1991-2010 and sourced from the World Development Indicators. We first estimate a panel Vector AutoRegressive (VAR) model and then implement the panel-data approach of Kónya (2006), based on Seemingly Unrelated Regressions (SUR) system and Wald tests with country specific bootstrap critical values. In the specific framework we use, we allow for cross-country correlation, without the need of pretesting for unit roots and cointegration (as in Phillips, 1995).

We propose to apply a bivariate finite-order vector autoregressive model to energy use or electricity consumption (E) and health (HEALTH): [1]

$$\begin{cases} E_{it} = \alpha_{1i} + \sum_{j=1}^{p_{1i}} \beta_{1,i,j} E_{it-j} + \sum_{j=1}^{p_{2,i}} \gamma_{1,i,j} HEALTH_{it-j} + \varepsilon_{1,i,t} \quad t = 1,...,T \; i = 1,...,N \quad (1a) \\ HEALTH_{it} = \alpha_{1i} + \sum_{j=1}^{p_{1i}} \beta_{2,i,j} E_{it-j} + \sum_{j=1}^{p_{2,i}} \gamma_{2,i,j} HEALTH_{it-j} + \varepsilon_{2,i,t} \quad t = 1,...,T \; i = 1,...,N \quad (1b) \end{cases}$$

[1] We are grateful to L. Kónya for providing his TSP codes, which we have adapted for our analysis.

where the index i $(i = 1,..., N)$ denotes the country, the index t $(t = 1,..., T)$ the period, j the lag, and p_{1i}, p_{2i} and p_{3i}, indicate the longest lags in the system. The error terms, $\varepsilon_{1,i,t}$ and $\varepsilon_{2,i,t}$, are supposed to be white-noises (i.e. they have zero means, constant variances and are individually serially uncorrelated) and may be correlated with each other for a given country, but not across countries.

System (1a, 1b) is estimated by the Seemingly Unrelated Regressions (SUR) procedure, since possible links may exist among individual regressions via contemporaneous correlation[2] within the two equations. Wald tests for Granger causality are performed with country specific bootstrap critical values generated by simulations.

With respect to system (1a, 1b), in country i there is one-way Granger-causality from HEALTH to E if in the first equation not all $\gamma_{1,i}$ are zero but in the second all $\beta_{2,i}$ are zero; there is one-way Granger-causality from E to HEALTH if in the first equation all $\gamma_{1,i}$ are zero but in the second not all $\beta_{2,i}$ are zero; there is two-way Granger-causality between E to HEALTH if neither all $\beta_{2,i}$ nor all $\gamma_{1,i}$ are zero; and there is no Granger-causality between E to HEALTH if all $\beta_{2,i}$ and $\gamma_{1,i}$ are zero.[3]

This procedure has several advantages. First, it does not assume that the panel is homogenous, so it is possible to test for Granger-causality on each individual panel member separately. However, since contemporaneous correlation is allowed across countries, it makes it possible to exploit the extra information provided by the panel data setting and therefore country-specific bootstrap critical values are generated. Second, this panel approach which generalizes the methodology developed by Phillips (1995) that tests for non-causality in levels VARs, in a time series context, does not also require pretesting for unit roots and cointegration, though it still requires the specification of the lag structure (which is determined here using the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC)). This is an important feature since the unit-root and cointegration tests in general suffer from low power, and different tests often lead to contradictory outcomes. Thirdly, this panel Granger causality approach allows the researcher to detect for how many

[2] This assumption is very likely to be relevant for many macroeconomic time series for African countries for which strong economic links exist.
[3] As stressed by Kónya (2006) this definition implies causality for one period ahead.

and for which members of the panel there exists one-way Granger-causality, two-way Granger-causality or no Granger-causality.

Data and variables choices

Four indicators were chosen in order to discuss the health outcomes. Firstly, life expectancy at birth as the most common health outcome indicator containing all information about health impacts. Improvements in health are translated in additional years of living. Secondly, under-5 child mortality since the most important effects is expected for children. Under-5 child mortality is one of the most important health outcomes. Thirdly, energy causes pollution and pollution causes health damage. We have tried to examine this indirect causality by considering air pollution. Finally we have examined a possible positive effect through the budget allocated to energy. As energy consumption and production grow, it may allow government to strengthen their health system by allocating more available revenue for health.

For energy we use energy consumption and electricity consumption. Energy consumption is an indicator of energy supply. It varies from a country to another mainly because the productive sector varies and its consumption varies. We would like to catch these differences in our analysis. At the same time we refine our analysis by examining the electricity consumption as a consumption of high-quality energy. Since Africa is increasing its access to electricity, one can expect to see some significant effects on health outcomes. In fact, as electricity consumption is more related to household energy consumption it has more important effects on health outcomes.

4. Empirical evidence of Energy Health nexus in Africa

In order to show the evidence of energy health nexus, we will start by discussing the link between energy consumption and the main health outcomes (direct and indirect links) before refining the analysis and focus only on electricity consumption effect on health outcomes.

4.1. Energy consumption and health outcomes in Africa

The links between energy consumption and Mortality rate, under-5

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%

Algeria	-0.3224	-.75170	7.3793	6.1038	5.0913
Benin	-0.0331	-.56388	2.3069	1.8775	1.4871
Cameroon	0.1179	1.9076**	2.0482	1.6508	1.3370
Democratic Republic of Congo	-0.0210	-.31700	6.3343	5.2180	4.1493
Egypt	-0.2504	-1.5199	11.7078	9.9552	8.6169
Ethiopia	-0.0687	-1.4365	5.1380	3.9952	3.0776
Ghana	-0.1377	-1.5797*	2.1117	1.7037	1.3870
Kenya	-0.1582	-2.9198*	4.4788	3.6049	2.8760
Morocco	0.0608	.68573	8.0484	6.8645	5.8442
Mozambique	-0.1049	-3.312***	2.4353	1.9678	1.5833
Nigeria	-0.0261	-.34562	2.1900	1.7358	1.4316
Senegal	0.0160	.60482	4.2183	3.4387	2.8143
South Africa	-1.5049	-1.2574	3.6078	2.9448	2.3885
Tanzania	-0.1394	-5.874***	2.6194	2.1515	1.7731
Tunisia	-0.2898	-1.3834	9.3009	7.9174	6.8380
Zambia	-0.1479	-1.1260	3.1931	2.5810	2.0778

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: Mortality Under-5 does not cause ***Energy*.**

Table 1a – Granger causality tests from Health to Energy consumption, bivariate (***Energy***, Mortality Under-5) model

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	-0.0154	-6.7666**	6.9266	5.5803	4.5913
Benin	0.0020	1.5761	3.9096	3.1560	2.5219
Cameroon	0.0094	6.3312***	5.5186	4.6401	3.9559
Democratic Republic of Congo	-0.0258	-5.4216***	4.3222	3.5030	2.7821
Egypt	0.0073	6.3197*	8.3779	6.7680	5.5949
Ethiopia	0.0162	3.7154**	4.2307	3.3893	2.7735
Ghana	0.0149	4.6325***	4.4847	3.6093	2.9318
Kenya	-0.0045	-.21473	4.3337	3.4443	2.8657
Morocco	0.0043	2.9869	8.2193	6.7830	5.6088
Mozambique	0.0064	3.3924	11.0358	9.5019	8.2426
Nigeria	0.0248	4.1523	10.4573	8.7712	7.5523
Senegal	-0.1335	-13.124***	6.2304	5.0157	4.1383
South Africa	-0.0071	-6.2283***	4.2208	3.3716	2.7011
Tanzania	-0.0124	-4.9785	9.9277	8.4917	7.1904
Tunisia	-0.0001	-.11920	6.3549	5.1053	3.9867
Zambia	0.0222	5.4244*	7.0726	5.8578	5.0060

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Energy*** does not cause Mortality Under-5.

Table **1b** – Granger causality tests from Energy consumption to Health, bivariate (***Energy***, Mortality Under-5) model

Tables 1a and 1b contain the results of the causality tests between energy consumption and mortality rate under-5 for a sample of 16 African countries for the period 1971-2010.

Our results show a unidirectional Granger causality from energy consumption to mortality rate under-5 for Algeria, Democratic Republic of Congo, Egypt, Ethiopia, Senegal,

South Africa, and Zambia. For these seven countries, we found strong links between energy consumption and one of the main health outcomes (children mortality). This result confirms our analytical discussion about the potential positive effect of energy use on Health. One plausible explanation is that in those countries there is a substitution between the sources of energy. People are using more high-quality energy and less low-quality energy like biomass. Since ten, citizens are less exposed to indoor pollution, are benefiting from more heating, warm food and better sanitation conditions. Our result shows that energy consumption is a good leverage for better health in Africa. It can be used in order to shortcut children mortality in Africa. We can remember that 80% of world child mortality is in Africa (AfDB, 2014 - HCS).

We further find a bidirectional Granger causality for Cameroon and Ghana at the 10%. The explanation of energy consumption effect on under-5 children mortality in these two countries relies on the same arguments than those previously explained. However, the retroaction effect is a novelty. One possible explanation is the fact that children mortality decrease indicates a change in the nature of the human capital in these countries and allows better production and growth for the country. As a consequence the energy consumption grows. It can be noticed that a unidirectional Granger causality from mortality rate under-5 to energy consumption for Kenya, Mozambique, and Tanzania is also found. We can also advocate the same explanations.

The links between energy consumption and life expectancy at birth

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	3.2174	1.0727	8.4199	7.0258	5.9627
Benin	0.2688	.46869	2.2469	1.8562	1.4822
Cameroon	-0.4608	-.63269	3.2501	2.6434	2.1042
Democratic Republic of Congo	0.1544	.10050	4.0624	3.3112	2.6999
Egypt	4.0019	2.2950	10.2678	8.6401	7.3473
Ethiopia	0.9720	1.9821	6.2713	4.9310	3.8923
Ghana	0.5853	.84106	2.0987	1.7046	1.3628
Kenya	0.1220	.35330	3.0108	2.4417	1.9867
Morocco	-0.3188	-.44997	8.9176	7.6152	6.6275
Mozambique	1.7344	2.7556***	2.7498	2.1614	1.7597
Nigeria	0.1617	.14326	2.0348	1.6242	1.3307
Senegal	-0.4280	-1.4097	4.4803	3.5860	2.9060
South Africa	-3.7992	-.89327	2.4334	1.9511	1.5911
Tanzania	1.1736	2.4779**	2.8089	2.2339	1.8028
Tunisia	2.4316	1.4685	10.0505	8.6191	7.3890
Zambia	1.6321	1.1192	3.8816	3.1206	2.5067

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: Life Expectancy at Birth does not cause ***Energy***.

Table 2a – Granger causality tests from Life Expectancy at Birth to Energy consumption model

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.0011	16.469***	11.0248	9.7769	8.7914
Benin	0.0008	11.094***	4.1493	3.3412	2.7477
Cameroon	-0.0011	-5.2056***	3.6968	3.0184	2.5491
Democratic Republic of Congo	0.0094	15.363***	5.5294	4.4466	3.7054
Egypt	-0.0009	-14.303***	4.9001	4.0157	3.2943
Ethiopia	-0.0011	-4.2125***	4.0844	3.2658	2.6409
Ghana	0.0010	1.8613	5.6523	4.5122	3.7206
Kenya	0.0201	10.261***	7.4824	6.3867	5.4427
Morocco	-0.0004	-3.5866	6.5486	5.4826	4.5393
Mozambique	0.0005	5.3356	12.2049	10.3832	8.8010
Nigeria	-0.0025	-9.8306	15.8256	14.3201	13.0581
Senegal	0.0046	19.310***	5.8636	4.8950	4.0417
South Africa	-0.0001	-2.6351	5.7361	4.6255	3.7424
Tanzania	0.0046	40.180***	16.2130	14.8707	13.5920
Tunisia	-0.0011	-1.4840	3.1921	2.5665	2.1053
Zambia	-0.0007	-1.3371	9.8478	8.3028	6.9503

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Energy*** does not cause Life Expectancy at Birth.

Table 2b – Granger causality tests from Energy consumption to Life Expectancy at Birth model

Tables 2a and 2b report the results of the causality tests between energy and life expectancy for a sample of 16 African countries for the period 1971-2010.

Our results show a unidirectional Granger causality from energy consumption to life expectancy for Algeria, Benin, Cameroon, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, and Senegal. Half of our sample confirms our analytical discussion about the possible impact of energy consumption on health assessed here by life expectancy. As Africa is growing, the income per capita increases allowing more per capita energy consumption. Energy consumption permits better sanitation, more heating and warm food, less indoor pollution and better medicines conservation. Our result is a strong result strengthened by the finding of a bidirectional Granger causality for Tanzania. For this country, the same arguments are valid for the link between energy consumption and life expectancy. However, the retroaction effect is also found. It is an expected result, since as life expectancy increases, the energy use need to be increased.

Evidence of a unidirectional Granger causality from life expectancy to energy consumption is found only for Mozambique. One plausible explanation is the fact that as life expectancy increases, energy consumption increases. While this result is expected for the entire sample, it was but found only in the case of Mozambique (and Tanzania). It may be explained by the fact that Mozambique has shown the most important impact in recent years.

The links between energy consumption and air pollution

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	13.0236	.9842	4.7131	3.8147	2.9667
Benin	11.4442	.64724	2.6245	2.1064	1.7164
Cameroon	9.4935	1.6249	3.3653	2.6734	2.1527
Democratic Republic of Congo	-40.1817	-1.5279	3.6725	2.9222	2.3111
Egypt	77.3073	3.1724	5.3894	4.3230	3.4960
Ethiopia	111.4398	.86359	4.0124	3.1839	2.4990
Ghana	-11.1861	-.19511	2.7219	2.1569	1.7601
Kenya	-40.0997	-3.2851*	4.5976	3.7221	2.9840
Morocco	36.0428	.79953	7.6621	6.4114	5.2446
Mozambique	10.1366	.28261	5.0191	4.0666	3.2699
Nigeria	-5.3890	-.65417	9.2876	7.8338	6.7430
Senegal	-14.9221	-1.1181	4.5266	3.5411	2.8888
South Africa	-22.4703	-.69359	3.3159	2.7129	2.2161
Tanzania	-142.4678	-3.1373**	3.6380	2.9948	2.3564
Tunisia	79.9783	2.2748	7.3406	5.9603	4.9666
Zambia	84.4599	7.9478**	8.1667	7.0705	6.0961

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: **Greenhouse** does not cause ***Energy***.

Table 3a – Granger causality tests from Greenhouse to Energy consumption model

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.00091	3.4335***	1.9443	1.5514	1.2557
Benin	-0.00029	-1.6961	3.8325	3.0870	2.4335
Cameroon	0.00040	.37132	3.8015	2.9706	2.3826
Democratic Republic of Congo	0.00017	2.1289	4.3261	3.4543	2.7978
Egypt	0.00087	2.9162	9.4349	8.1525	7.0484
Ethiopia	0.00009	1.6495	3.8558	3.1515	2.5475
Ghana	0.00100	5.4220***	3.1129	2.5230	2.0541
Kenya	0.00080	1.7277	3.7496	3.0272	2.4121
Morocco	0.00107	1.6115	10.6206	9.2137	7.7765
Mozambique	-0.00003	-.32141	5.2126	4.3583	3.6068
Nigeria	-0.00085	-2.0137	5.8873	4.7023	3.8401
Senegal	0.00039	1.2716	2.0552	1.6665	1.3398
South Africa	0.00059	1.3352	3.9152	3.2859	2.6758
Tanzania	0.00042	4.7859*	5.7094	4.6977	3.8633
Tunisia	0.00146	5.2926**	6.3266	5.1848	4.1940
Zambia	-0.00025	-.95378	6.8369	5.6581	4.7463

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Energy*** does not cause ***Greenhouse***.

Table 3b – Granger causality tests from Energy consumption to Greenhouse model

Tables 3a and 3b show the results of the causality tests between energy and greenhouse effect.

Our results show that energy consumption is causing air pollution in Algeria, Tunisia and Ghana. Per capita consumption of energy is among the highest in the Continent in Tunisia and Algeria. Those economies are transforming and the demand for energy is fast growing implying air pollution. One plausible explanation is that those countries are in the first phase of the Kuznets curve where economic growth is accompanied by pollution (Arouri et al. 2012). One can also note that these two countries are among the most urbanized in Africa and that urbanization foster air pollution [Ref]. Ghana is fast growing and its per capita energy consumption is also fast growing implying air pollution. The same explanation than Tunisia and Algeria is valid while the per capita income is different. What is happening in Tunisia, Algeria and Ghana is expected also to happen to the other African countries.

Our results show also bidirectional Granger causality for Tanzania, at the 10% or lower level of significance. While the link between energy consumption and air pollution can be easily explained by economic growth and perhaps the use of biomass as main source of energy; the reverse link is less easily explained. Greenhouse effect may lead some counties to use more the air conditioning and by this increase their energy consumption. The evidence of a unidirectional Granger causality from greenhouse to energy consumption for Kenya, and Zambia can also be explained by the same fact.

The links between energy consumption and government health expenditure per capita

Tables 4a and 4b report the results of the causality tests between energy and Government health expenditure.

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.2250	1.16078	31.5603	24.1557	19.0303
Benin	4.4351	6.86810	27.5836	21.4818	16.8741
Cameroon	-1.4985	-2.82614	35.4122	27.0757	20.7601
Democratic Republic of Congo	0.4627	.773530	35.5358	26.4677	20.3036
Egypt	-1.0411	-1.66078	30.8394	23.6045	18.6338
Ethiopia	6.8039	16.8518*	33.0780	24.7014	14.8476
Ghana	-0.5306	-3.55917	26.8016	20.1940	16.1548
Kenya	1.2757	3.02414	43.3785	32.9441	25.8460
Morocco	1.0578	2.48531	39.8954	31.3489	24.3084
Mozambique	3.0208	11.8271	38.1888	30.0408	23.7969
Nigeria	0.4513	2.70139	17.8765	14.5432	11.0987
Senegal	3.1396	5.97976	19.9071	15.2771	12.1574
South Africa	-0.5580	-2.36808	29.1143	22.3234	17.4075
Tanzania	0.2250	11.14249	30.4655	22.2426	18.1762
Tunisia	4.4351	9.10458	17.2637	14.1151	11.0764
Zambia	-1.4985	7.3426	28.3812	25.2205	19.1641

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: Government **health** expenditure per capita does not cause ***Energy***.

Table 4a – Granger causality tests from Government **health** expenditure per capita to Energy consumption model

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.3287	9.23906*	31.3104	24.2821	9.1911
Benin	0.0107	1.37080	27.4500	20.5580	15.6580
Cameroon	-0.0156	-1.58181	23.1895	17.9419	13.6062
Democratic Republic of Congo	0.0110	2.18518	25.0483	19.4576	14.9910
Egypt	0.0236	6.16102	38.0513	27.5071	19.0758
Ethiopia	-0.0310	-16.0195*	34.9817	27.9748	12.0003
Ghana	0.0631	1.71180	41.8271	32.9599	25.6130
Kenya	0.1132	3.90737	9.6338	7.4824	5.9461
Morocco	0.1167	6.70038*	23.3377	13.1529	6.5095
Mozambique	0.0354	1.79486	41.7964	32.4499	25.3856
Nigeria	0.0779	3.89060*	5.0191	4.0666	3.2699
Senegal	-0.0044	-.201174	38.9076	22.0789	14.0938
South Africa	0.0438	3.20691	27.2186	21.8501	17.4535
Tanzania	0.3287	2.13476	23.1643	19.5056	15.8260
Tunisia	0.0107	5.86543	17.3406	15.9603	14.9666
Zambia	-0.0156	3.09865	38.1667	27.0705	16.0961

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Energy*** does not cause Government **health** expenditure per capita)

Table 4b – Granger causality tests from Energy consumption Government **health** expenditure per capita model

There is no evidence of Granger causality from government health expenditure to energy consumption, of Granger causality from energy consumption to government health expenditure for Algeria, Morocco, Nigeria, and of a bidirectional Granger causality for Ethiopia, at the 1% level of significance.

As energy consumption grows, the revenue generated (directly: through production of energy or indirectly through taxation of energy consumption) allows more government expenditure on health in Algeria, Morocco, and Nigeria. Algeria and Nigeria are big oil producers. The domestic consumption of energy and the government health expenditure are strongly linked to the oil production rent and the better awareness of those countries about the health investment. Investing in health and energy consumption is expected to help the countries to invest in human capital and making the necessary economic transformation of the countries.

While for the case of Morocco, the relation seems more correlated to the increasing income per capita and better fiscal policies allowing increasing the health expenditure. For the case of Ethiopia, we found a feedback effect. In fact, as the energy consumption grows, the economic activities grows and allows more resources for the government that re-invest them

in public expenditures in matter of health allowing better human capital. People are becoming more educated and in better health increasing their productivity which increase their revenues and as a consequence their energy consumption. Ethiopia is perhaps the virtue circle that may occur in different parts in Africa in the next decade.

4.2. Electricity consumption and health outcomes

The links between electricity consumption and child mortality under-5

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.3138	1.2673	6.2883	5.1104	4.2314
Benin	-0.0899	-2.6585	10.7969	9.4348	8.2539
Cameroon	-0.1390	-1.0128	9.5972	8.3618	7.3932
Democratic Republic of Congo	0.1448	1.5035	6.4916	5.4421	4.5232
Egypt	0.0008	.73312	4.3154	3.5576	2.8902
Ethiopia	0.0017	.18262	3.0056	2.4021	1.9544
Ghana	0.1961	.75527	3.7728	2.9722	2.3359
Kenya	-0.0664	-1.5163	5.4289	4.5317	3.7025
Morocco	-0.0545	-.47071	7.1190	5.9510	5.0396
Mozambique	-0.6531	-3.7959	10.6425	8.8989	7.6470
Nigeria	-0.4823	-5.2859***	4.7055	3.6224	2.9585
Senegal	-0.0902	-1.9145	8.8678	7.6787	6.5624
South Africa	-4.7735	-2.3154	7.6241	6.3484	5.2870
Tanzania	-0.1064	-2.6116	5.8902	4.6894	3.7010
Tunisia	-0.1089	-.61200	6.6711	5.6962	4.7469
Zambia	0.0356	.13819	3.6759	2.9481	2.3659

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: Child Mortality under-5 does not cause ***Electric Consumption***.

Table 5a – Granger non-causality tests from Child Mortality under-5 to Electric Consumption model

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.0040	1.5855	7.5674	6.0284	4.9644
Benin	0.0030	.74265	3.6752	2.9910	2.3797
Cameroon	-0.0073	-6.2015***	1.8555	1.4809	1.1765
Democratic Republic of Congo	-0.0078	-1.9993	8.9473	7.5185	6.5549
Egypt	0.0062	9.4544***	6.4583	5.1216	4.1407
Ethiopia	0.2118	5.9007**	6.1666	5.1067	4.1770
Ghana	0.0033	3.1369*	4.4879	3.5102	2.8194
Kenya	0.0360	1.7378	7.1101	5.8552	4.7369
Morocco	0.0067	6.2858**	6.7409	5.4880	4.5323
Mozambique	0.0032	2.2127	4.9570	4.1199	3.3122
Nigeria	0.0709	7.1768**	8.1650	6.7646	5.6090
Senegal	-0.0789	-5.6725**	5.8768	4.8717	4.0309

South Africa	0.0003	.51312	5.5049	4.4679	3.6767
Tanzania	-0.0490	-2.7879	6.0762	4.8094	3.9432
Tunisia	0.0002	.69591	5.9257	4.7682	3.8647
Zambia	0.0083	6.6783***	4.3276	3.5546	2.8859

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Electric Consumption*** does not cause Mortality under-5.

Table 5b Granger non-causality tests from Electric Consumption to Child Mortality under-5 model

Tables 5a and 5b show the results of the non-causality tests between electric consumption and under-5 child mortality for a sample of 16 African countries for the period 1971-2010.

As expected, there is no evidence of a unidirectional Granger causality from health to electric consumption. There are no or few arguments explaining this link.

In contrast, there is as expected evidence of a unidirectional Granger causality from electric consumption to under-5 child mortality for Cameroon, Egypt, Ethiopia, Ghana, Morocco, Senegal, and Zambia. As we have largely argued in our theoretical framework, increasing the electricity access has strong effect on child mortality. Access to electricity allows better conditions for cooking and heating and avoiding by this indoor-pollution and associated diseases.

There is evidence of a bidirectional Granger causality for Nigeria, at the 10% or lower level of significance. While the same arguments occur for the link between electricity consumption and under-5 child mortality. Electricity consumption has differentiated effects on Life expectancy at birth in Africa.

The links between electricity consumption and Life expectancy at birth in Africa

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	-0.8152	-.26404	10.1623	8.8595	7.5790
Benin	0.7580	2.2599	9.4260	8.2751	7.2234
Cameroon	-1.4156	-1.1224	3.6365	2.8592	2.2655
Democratic Republic of Congo	-0.3808	-.22240	3.9140	3.1412	2.5439
Egypt	2.2970	1.2607	7.5835	6.5897	5.6134
Ethiopia	0.1232	1.1628	2.9434	2.4395	1.9375
Ghana	-1.6290	-.73963	3.5755	2.9355	2.4026
Kenya	-0.1149	-.61176	3.7775	3.0337	2.4746
Morocco	0.7022	.74623	8.6844	7.3798	6.3107
Mozambique	11.1951	4.5291	10.1219	8.2743	7.0615
Nigeria	7.3483	5.2233***	4.1568	3.2115	2.5936
Senegal	0.6891	1.3912	10.6114	9.1119	7.9628
South Africa	3.5138	.60428	3.4272	2.7636	2.2785

Tanzania	0.2528	.65758	3.9264	3.0787	2.4391
Tunisia	0.3471	.21902	7.0976	6.0148	5.0962
Zambia	-2.3867	-.70231	4.8817	3.9590	3.1572

***. **. *: Significance at the 1%. 5% and 10% levels respectively.

H_0: Life Expectancy at birth does not cause ***Electric Consumption***.

Table 6a – Granger non-causality tests from Life Expectancy at birth to Electric Consumption model

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.0002	3.4796	6.1314	5.2088	4.4440
Benin	0.0032	12.164***	5.1562	4.3235	3.6238
Cameroon	0.0011	2.9750**	3.1627	2.5440	2.1017
Democratic Republic of Congo	0.0012	3.9945***	3.9734	3.2048	2.6206
Egypt	-0.0012	-8.9471***	8.7046	7.5388	6.5467
Ethiopia	-0.0014	-.82955	8.8356	7.5850	6.6644
Ghana	-0.0004	-6.5374***	4.2630	3.3866	2.7887
Kenya	-0.0051	-5.9395	9.1998	7.8263	6.8357
Morocco	-0.0006	-9.8376***	9.4096	8.1676	7.1513
Mozambique	0.0001	1.9715	5.6865	4.6380	3.8156
Nigeria	-0.0066	-9.2836*	11.5142	10.3395	9.1729
Senegal	0.0031	10.235***	4.0868	3.3227	2.7214
South Africa	-0.0003	-10.608***	6.0586	4.9651	4.0556
Tanzania	0.0039	4.7617	9.1095	7.9267	7.0043
Tunisia	-0.0004	-.93995	4.9187	4.0493	3.3819
Zambia	0.0006	4.9866	8.1255	6.7444	5.6374

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Electric Consumption*** does not cause Life Expectancy at birth.

Table 6b Granger non-causality tests from Electric Consumption to Life Expectancy at birth model

Tables 6a and 6b contain the results of the non-causality tests between electricity consumption and health (Life expectancy at birth).

Our results show contrasted results in matter of electricity consumption and health. Two sub-groups of countries have significant links between electricity consumption and life expectancy at birth. In fact, It can be noticed no unidirectional Granger causality from health to electricity consumption, a unidirectional Granger causality from electricity consumption to health for Benin, Cameroon, Democratic Republic of Congo, Egypt, Ghana, Morocco, Senegal, and South Africa, and a bidirectional Granger causality for Nigeria, at the 10% or lower level of significance.

We found negative unidirectional causality from electricity consumption to life expectancy for South Africa, Nigeria, Ghana, Morocco, and Egypt. This finding is surprising! As electricity consumption increases the life expectancy at birth decreases?

However, we found positive unidirectional causality from electricity consumption to life expectancy for Benin, Cameroon, DRC and Senegal (West and Central Africa). As

electricity consumption increases the life expectancy increases. Most of these countries have very low per capita consumption of electricity and poor coverage of the grid. Most rural areas are lacking access to electricity.

Two plausible explanations may be presented. Firstly, the consumption of electricity has raised the budget allocated to energy and lower the budget for health. If we consider that electricity is subsidized like in some countries (Tunisia, Egypt…). As consequence, the energy poverty acted in a way that lowered life expectancy at birth. Secondly, as the consumption of electricity increased, the production has followed the same trends. The problem comes from the technologies used for the production of electricity. Electricity provision can be based on several types of technologies with differentiated effects ion health. While green technologies like wind power and hydropower have (no) or small health impacts, other technologies based on Coal, Gasoil, etc....have deep impacts on health. Several reports show local air pollution due to SO2 emissions, NOx emissions and others GHG. The combined effect may be negative in the short run. Other explanations rely on the fact that electricity consumption may led to harmful behaviors: watching TV for hours, less sport activity and more time spent on screens, etc…

The links between electricity consumption and Government health expenditure per capita

	Estimated coefficient	Test Statistic	Bootstrap critical values		
			1%	5%	10%
Algeria	0.2250	1.1607	26.9015	21.1294	17.0864
Benin	4.4351	6.8681*	12.8411	10.2525	6.1209
Cameroon	-1.4985	-2.8261	43.6980	35.7427	29.5664
Democratic Republic of Congo	0.4627	.77353	30.6792	22.9657	17.6127
Egypt	-1.0411	-1.6607	23.2006	18.5671	14.7963
Ethiopia	6.8039	16.851*	23.3752	18.5415	14.7213
Ghana	-0.5306	-3.5591	5.2224	4.2231	3.4805
Kenya	1.2757	3.0241	32.1537	25.1697	19.2141
Morocco	1.0578	2.4853	29.7854	23.4288	18.5749
Mozambique	3.0208	11.827	29.7471	23.5034	18.6776
Nigeria	0.4513	2.7013	21.3035	16.4112	13.3047
Senegal	3.1396	5.9797	13.0377	10.3030	8.1585
South Africa	-0.5580	-2.3680	20.2443	15.6382	12.0435
Tanzania	0.2250	-3.3546	9.3456	8.1873	7.8765
Tunisia	0.3924	2.2346	11.5123	9.1265	6.9086
Zambia	0.2454	1.9876	16.9216	14.9654	11.4567

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: *Health expenditure per capita* does not cause ***Electric Consumption***.

Table 7a – Granger non-causality tests from *expenditure per capita* to Electric Consumption model

	Estimated	Test Statistic	Bootstrap critical values

	coefficient		1%	5%	10%
Algeria	0.3287	9.2390*	17.7488	9.6706	7.0807
Benin	0.0107	1.3708	26.4519	20.0469	16.1444
Cameroon	-0.0156	-1.5818	24.1989	19.0736	15.1717
Democratic Republic of Congo	0.0110	2.1851	24.6775	19.3065	15.2766
Egypt	0.0236	6.1610	41.4677	29.4222	16.0679
Ethiopia	-0.0310	-16.019*	37.1127	28.5266	12.5332
Ghana	0.0631	1.7118	43.0568	34.3979	27.2814
Kenya	0.1132	3.9073	9.3856	7.3393	5.8544
Morocco	0.1167	6.7003	49.7991	32.2589	20.4923
Mozambique	0.0354	1.7948	41.3394	32.1611	25.2466
Nigeria	0.0779	3.8906	51.7398	41.4223	32.9166
Senegal	-0.0044	-.20117	28.4903	22.2955	17.2014
South Africa	0.0438	3.2069	53.1188	42.7987	35.0586
Tanzania	0.0456	4.4567	38.1786	34.6578	29.6543
Tunisia	-0.0324	3.6543	45.6754	38.1765	31.4567
Zambia	0.0235	1.5487	23.8796	19.8976	16.0098

***. **. *: significance at the 1%. 5% and 10% levels respectively.

H_0: ***Electric Consumption*** does not cause *Health expenditure per capita.*

Table 7b Granger non-causality tests from Electric Consumption to *Health expenditure per capita* model

Tables 7a and 7b report the results of the non-causality tests between electricity consumption and Government health expenditure per capita for a sample of 16 African countries for the period 1971-2010. Evidence of a unidirectional Granger causality from health to electricity consumption is found for Benin. Evidence of a unidirectional Granger causality from electric consumption to health for Algeria, and a bidirectional Granger causality for Ethiopia, at the 10% or lower level of significance.

4.3. Discussion

Our results show that there is strong impact of energy use in Africa on under-5 children mortality and life expectancy. The evidence is found for at least eight countries having different levels of income per capita. The results are robust in fragile states like DRC and Côte d'Ivoire and Middle Income Countries like Tunisia and Morocco. One can expect that the effect of increasing energy consumption will be strengthened in the near future given the current low level of energy consumption. As per capita electricity consumption represents in SSA 1% of the European consumption level, there is an expected "health effect" in the near future of energy consumption. Moreover, we found an evidence of the link between energy consumption and Government health expenses. The revenues generated by the domestic

consumption of energy are partially recycled in health care and medicines. Our results did not show significant trends between energy use and electricity consumption.

5. Policy implications

Increasing access to modern sources of energy and electricity implies an improvement in cooking conditions and heating (lowering the risk associated with indoor air pollution), in health centers' infrastructure (improving child and maternal health), in medicines conservation, and provides more incentives for health workers. The overall effect of such improvement is a healthier workforce, and an increase in life expectancy.

Recent economic growth in Africa allows more investment in health, education, infrastructure, and electrification. With increasing per capita income Africans can invest more in energy use and electricity and substitute their energy sources from pollutant ones (biomass) to less pollutant ones (Electricity, GPL). At the same time, Africa is benefitting from the technological latter comer effect. Africa is benefitting from latest technologies for provision of electricity (more efficient and cheaper technologies), especially in matter of renewable energies. While this "market dynamic" seems important, it will not be sufficient to help Africa bridge its divide in energy use and electrification. There is a strong need that must be fulfilled with Global initiatives, local and regional policies especially to improve the health impacts of energy access.

> The most prominent global initiative for the provision of energy for African is the newly launched initiative of the Secretary General of the United Nations toward ''Sustainable Energy for All'' (http://www.sustainableenergyforall.org/). The UN and most of development agencies have putt African households high in their agenda. Energy poverty seems one of the major components of poverty nowadays and even in developed countries, millions of people are facing this kind of poverty, which impacts their health, education and labor performances. This initiative targets universal access to electricity in Africa by 2025. The seventh goal of the Sustainable Development Goals (SDG) also aim to ensure universal access to affordable, reliable and modern energy services by 2030[4].

[4] **7.1:** By 2030, ensure universal access to affordable, reliable and modern energy services
7.2: By 2030, increase substantially the share of renewable energy in the global energy mix
7.3: By 2030, double the global rate of improvement in energy efficiency

Initiatives in matter of improving the cooking stoves like the Global Alliance for Clean Cookstoves (http://www.cleancookstoves.org/) are innovative solutions in order to decrease health risks due to indoor pollution. Switching the cooking stoves has a great potential to reduce the risk of death and chronic diseases associated to indoor air pollution. Improved access to modern energy services including cleaner-combusting and more efficient cooking fuels like LPG, biogas, natural gas and an advanced biomass stove reduce the health risks. It also has an impact on reducing carbon emissions in developing countries (Bond et al., 2013; Shindell et al., 2012). Several measurement campaigns have evaluated the performance of improved stoves and fuels, including the evaluation of climate relevant species (Maccarty et al., 2007, 2010), and the potential health benefits of their introduction (Anenberg et al., 2012). In addition to resulting in significant health benefits, recent assessments suggest that such residential cooking fuel and stove switching, may also have a greater potential to curb global warming by reducing black carbon emissions. The major challenge in Africa is the access to these technologies at an affordable cost.

Last mile policies need also to be strengthened. Most of African infrastructure projects especially in of the area of transport, energy and water need to consider the last mile to health care, schools and public facilities as part of the projects. In fact, several schools, health care and public facilities (especially in rural Africa) lack electricity despite the proximity of an electricity grid. Insufficient resources and non-consideration of health and education aspects in infrastructure projects lead to a situation where people have no access to basic health services because of lack of electricity. For instance, maternal health services need to be close to the population but are often not available due to absence of electricity and energy sources.

6. Concluding remarks

The objective of this article was to discuss the causality links between energy consumption and health outcomes in Africa. We proposed an analytical framework to identify the expected causality links and an econometric analysis of this causality for 16 countries during the period 1971-2010.

7.4: By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

7.5: By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

Our analysis suggests a strong link between energy consumption and decreasing under-5 child mortality on the one hand and increased life expectancy on the other hand. The causality is well-established for more than half of the countries under study in several regions of Africa and at different levels of development.

The examination of the same causality for electricity consumption and health outcomes confirms the previous results, while showing surprising links for life expectancy. There is a negative effect in the case of five large African countries: South Africa, Nigeria, Ghana, Morocco, and Egypt. We found also the evidence of a causality link between energy use, electricity consumption and government spending in health.

Our results advocate for improving electricity provision for Africans. Health externalities (considered as positive externalities) can balance the potential environmental negative externalities. Africa contribution to Greenhouse effect is very limited (less than 5%) and is marginal compared to countries such China and United States. While it is important that Africa grows using cleaner technologies and fosters the use of renewable energies (following a sustainable pathway), there is also urgency for Africans to use more energy (especially electricity) to reverse the dramatic health and sanitation situation leading to maternal and child morbidity and mortality. It is also urgent to implement new technologies based on electricity out of the grid in rural Africa, where most important problems are reported.

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