ENERGY DIVERSIFICATION OF SOURCES IN SUB-SAHARAN AFRICA: What Impact On Quality Of Life?

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Abstract:

The aim of this paper is to assess the effect of diversification of energy sources on quality of life in Sub-Saharan African countries from 2000 to 2015. Using the Shannon Wiener, Stirling (1999-2000) index and several estimation methods, our results show that diversification of energy sources has a positive influence on the quality of life. However, these countries should promote the diversification of energy sources through a specific structural change allowing a policy of decentralization of power generation, because improving access to energy increase in life expectancy of the population.

Keywords: Energy Diversification of sources, Quality of life, Shannon Wiener Index

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1. INTRODUCTION

Developing countries in general and Sub-Saharan African (SSA) countries in particular face energy challenges. However, diversification of energy sources ensures the security of electricity supply, Stirling (1999 and 2001), as well as environmental security to the interest of intergenerational equity (Percebois, 2001). Despite the wealth of natural resources in SSA, the population's energy consumption is based on hydropower, fossil fuels and biomass, about 80% according to IEA (2002). The studies conducted by ADEA (2015) present the inequalities of access to energy at the regional and national levels in Africa. The rate of access to electricity is 99% in North Africa and 32% in sub-Saharan Africa. SSA is an energy paradox. Most households in SSA use biomass to meet their energy needs. Due to poor ventilation, biomass generates high indoor pollution that impacts health (Bruce et al., 2000). Yet energy is essential for life and economic development (Djiby, 2011). Diversification of energy sources is necessary, as access to energy is fundamental for human well-being (Morrissey,2017). In view of this energy potential, it is important to understand that diversification of energy sources could affect the quality of life by improving people's access to energy.

Diversification of energy sources is based on the energy that is necessary for socio-economic development. Diversifying energy sources requires adequate technology to extract useful energy, hence the innovation of technology (Schumpeter, 1935; Arrow, 1962; Rosenberg 2008, 1982; Guellec 2003). Although many studies have been devoted to the issue of energy and quality of life (Jones et al., 1996; Kanagawa et al., 2008, Pasten and Santamarina, 2012; Almulai, 2016; Nadimi et al., 2017; Nadimi and Tokimatsu, 2018), very few have analysed source diversification and quality of life. The work of Stirling (2001), Nwofor et al. (2007), Rosenberg (2008), Ross (2014) lay emphasis on the fact that the diversification of energy sources ensures; (1) the security of energy supplies, (2) substantial improvement of the living conditions of populations, (3) favouring the fight against hunger and malnutrition, (4) positively affecting the health of the environment (restriction of CO_2 and GHG emissions), and (5) the quality of life (improvement of human health through the reduction of cardiovascular diseases, facilitation of access to water...).

The objective of this paper is to analyse the effect of diversification of energy sources on environmental quality in SSA. This effect will be analysed based on the link between energy and several quality-of-life indicators (health, education, and access to water). This paper contributes to the debate on the impact of energy diversification in SSA by evaluating Shannon Wiener's energy diversification index and econometric estimation to prove that energy diversification is a way out of energy scarcity. To achieve this objective, several estimation techniques were used: the random effect method (RE), the least squares method on stacked data (PLS), and the generalized method of moments (GMM) which corrects for endogeneity biases. The results obtained show the positive influence of energy diversification on the short-term quality of life in SSA.

The rest of the article is organized into three additional sections. Section 1 presents a brief review of the literature, Section 2 discusses the methodological approach and data, while Section 3 deals with various results obtained and followed by the conclusion, where some few policy recommendations will be identified.

2. LITERATURE REVIEW

Literature review highlights the reasons why a perspective of diversification of energy sources is important for SSA countries as an exit solution to energy scarcity, and an essential condition for socio-economic and human development (Avadikyan and Mainguy, 2016). However, diversifying energy sources ensures security of electricity supply (Stirling, 1999 and 2001). Similarly, it also helps to protect against political risks in a given region and reduces the risk of supply disruption (Artigues, 2008). While there is general agreement on the value of the diversification of energy sources, it is important to consider what this concept means in terms of how to measure the diversity of an electricity system. Much work refers to Stirling's research, which conceives diversity as a means of making systems resistant to uncertainty, risk, or ignorance. Stirling (1999) develops indicators of energy diversity. He distinguishes three essential properties of a diverse system: variety, balance, and disparity. ***Variety,*** is a positive integer measuring the number of categories in which different primary energy sources are classified, or further analysed, by different energy conversion technologies; ***Balance,*** is a concept measuring the homogeneity of the relative proportions of different primary energy sources; and ***Disparity,*** refers to the nature of the categories of primary energy sources and measures the degree of differentiation of the categories among them. For example, the categories "oil" and "natural gas" are less disparate than the categories "oil" and "renewables". Disparity is an inherently qualitative, subjective, and context-dependent aspect of diversity. Given the number of primary energy sources, energy diversity is very high in such a way that a greater regularity on the distribution process is observed.

There are two main methods for assessing the diversity of a system or portfolio of energy sources:

-The first is the use of sophisticated techniques.

-The second is the calculation of quantitative indicators (Grubb et al., 2006; Jansen et al., 2004), the vast majority of which have been developed in biology and ecology, while other disciplines such as economics and computer science have been reserved for extensive development (Stirling, 1999 and 2001).

In the case of this study, it is the second method of evaluating the energy diversification that is taken into account, as it emphasizes security in the course of supply. Two indicators are used to measure diversity: the Shannon Wiener Index (SWI) and this Simpson is indicator, also known as the Herfindahl-Hirschman Index (HH). They are the most commonly used in the energy literature.
In this work, the index used is that of Shannon Wiener (SWI). It allows a coherent aggregation of the heterogeneity between different levels of hierarchy of a system, sometimes simply called Shannon's index, whose formulation is as follows:

$$SWI = \Delta_{ener} = -\sum_i p_i \ln p_i$$

Where p_i represents the proportion of electricity generated from the primary energy source *i*, which can be wind, solar, hydro, or geothermal. It must be noted that this indicator is widely used to account for diversification of energy sources (Grubb et al., 2006; Jansen et al., 2004 among others). It should be noted that the higher the value taken by this index, the more diversified the mix, and lower values indicate an unfavourable situation in terms of energy diversity.

Empirical studies on the impact of energy diversification on quality of life are few and almost non-existent in SSA. With this in mind, inspiration was being drawn from the work on energy and quality of life to furnish our literature review. This positioning stems from the fact that the concept of diversification of energy sources has an energy anchor. Several studies show a good correlation between energy and quality of life by highlighting four social indicators (GNP, literacy rate, infant mortality, fertility) that materialize quality of life (Jones et al., 1996; Kanagawa et al., 2008, Pasten and Santamarina, 2012; Liu et al., 2016; Usama Al-mulali, 2016; Nadimi and Tokimatsu, 2018). With regard to the work on energy diversification and quality of life, studies have shown a positive correlation between the two concepts. Diversification of energy sources improves the standard of living of individuals and increases their life expectancy (Nwofor et al., 2007; Rosenberg, 2008; Ross, 2014). The analysis is based on studying this effect by calculating the SWI index and estimating it by an econometric model on the panel.

3. METHODOLOGICAL STRATEGY

The methodological strategy is presented in two consecutive steps: the empirical model and the estimation method.

3.1. Empirical model

In this paper, the impact of energy diversification on the quality of life in SSA over a sample of 20 countries[1] during the period 2000 to 2015 was analysed. The analytical model used is based on those used in studies on the analysis of the effect of energy on the quality of life, notably by (Pasten and Santamarina, 2012; Usama Al-mulali, 2016; Nadimi et al.,2017; Nadimi and Tokimatsu, 2018). The model to be estimated is written as follows:

$$QoL_{it} = \alpha_i + \delta_i t + \beta_1 SWI_{it} + \beta_2 EPCC_{it} + \beta_3 GDPC_{it} + \varepsilon_{it}$$

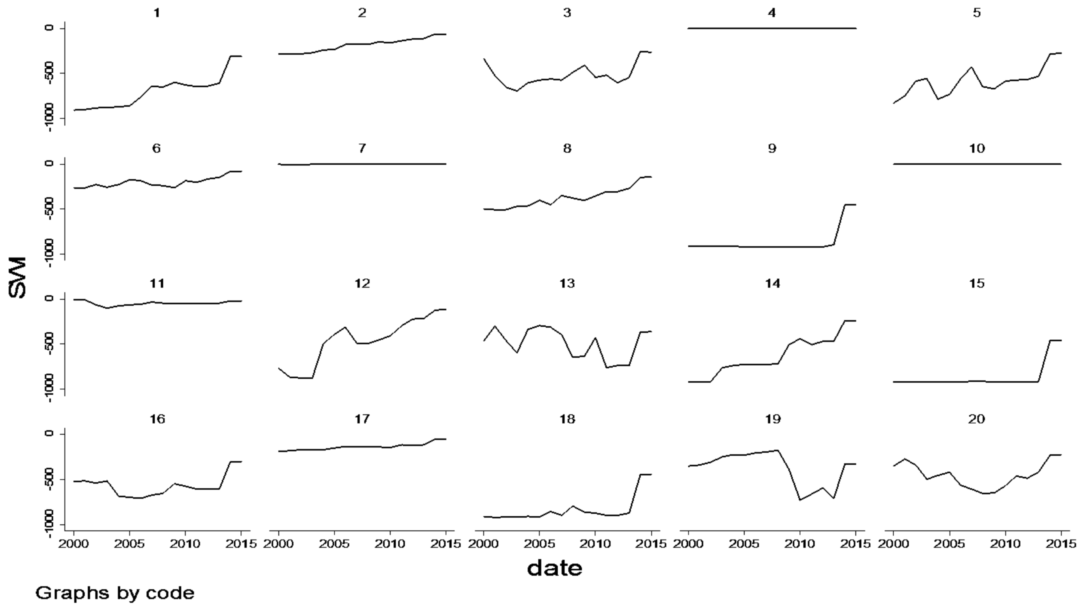
With α_i fixed effects, δ_i is the trend coefficient, $\beta_{1,},....,\beta_3$ are the regression coefficients, ε_{it} term of the error. Note that QoL_{it} represents the endogenous variable which is the quality of life of a country *i* (*i*= *1,2,..., N) in* year *t* (*t*=*1,2,..., T*). The set of exogenous variables is the energy diversification index (SWI), income per capita (GDPC) expressed in dollars, and electric energy consumption (EPCC) in Kwh per capital.

3.2. Data and measurements of variables

The data used for the estimate are annual. They originate mainly from the World Bank's *World Development Indicators* (WDI) databases, 2016 edition. The quality-of-life variable (QoL), which is endogenous in our study, is obtained by synthesizing several indicators: life expectancy/years (LEF), the mortality rate of children aged 0 to 1 year/1000 at birth (IMR), access to drinking water as a percentage (IWA), and the schooling rate per year (EDUC). Graph 1 shows the evolution of the quality of life in the SSA countries.

This evolution over the period 2000-2015 shows that the vast majority of SSA countries are in the process of developing or even improving their quality of life, which varies from -2 to 2 and more, although in some countries it is stable.

[1] Cameroon, Nigeria, Kenya, South Africa, Ghana, Côte d'Ivoire, Benin, Gabon, Mozambique, Niger, Senegal, Tanzania, Togo, Congo, Democratic Republic of the Congo, Angola, Mauritius, Namibia, South Africa, Sudan, and Zimbabwe.



Source: Author

Graph 1: Evolution of the energy diversification index in SSA countries between 2000-2015

- One of the exogenous variables is the Energy Source Diversification Index, which is calculated from the Shannon Wiener Index (SWI)[2] developed by Stirling (1999). Stirling uses diversity as a concept with three subordinates: variety, equilibrium and disparity. We calculate this index from the totality of renewable energies in SSA (hydraulic, solar, wind, geothermal...). Graph 2 shows its evolution within the SSA countries. It can be noted that Nigeria, South Africa, Benin, Niger, Senegal, and Angola have a more diversified energy structure than other SSA countries which are in the process of diversifying their energy sources and others such as Mozambique, for example, which are stagnant. Referring to the theory of energy diversification, a high value of this index indicates more diversification (Grubb et al., 2006).

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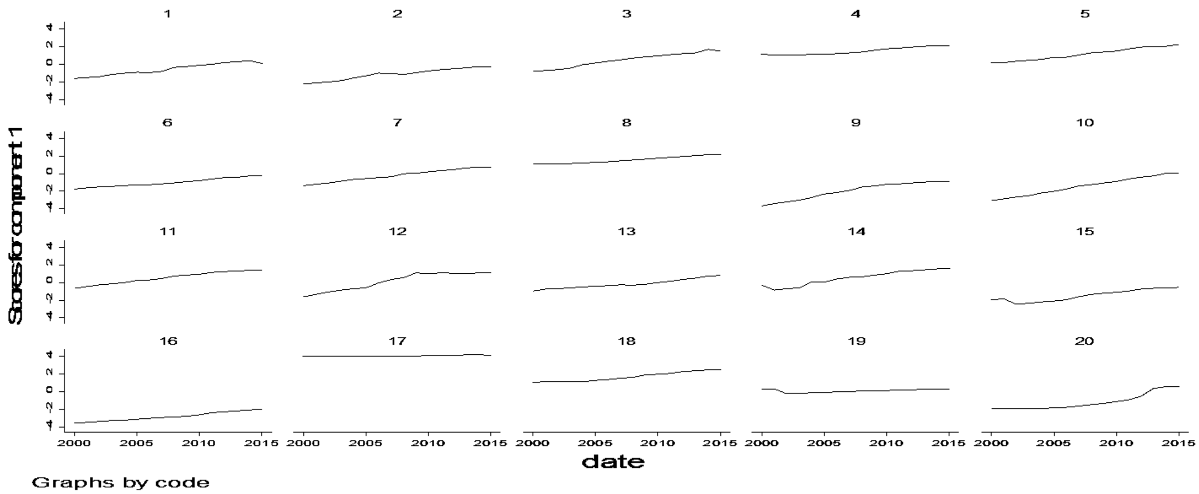
[2] Shannon Wiener's method of calculating the Shannon Wiener Index developed in Chapter 1. The Shannon-Wiener Diversity Index Δ_{ener}, illustrates the energy diversification index, calculated for the primary energy portfolio, whose formula is:

$$\Delta_{ener} = -\sum_i c_{1i} p_i \ln p_i$$

In this expression, p_i represents the share of primary energy *i* in the total primary energy sources, with $i = 1, ..., M$ (*M* being the number of energy sources). c_{1i} is a correction factor of p_i for the indicator Δ_{ener}, equal to the unit for this first indicator.



Source: Author.

Graph 2: Changes in quality of life in SSA countries from 2000-2015

Other exogenous variables include income per capita (GDPC) expressed in constant dollars to capture economic growth, and electrical energy consumption (COEP) measured in kilowatt hours per capital. Table 1 below presents descriptive statistics for the various variables used in our study.

Table 1. Summary statistics of 2000-2015

Variable	obs	Mean	Std.Dev	Min	Max
Qol	320	-3.50e-09	1.6649	-3.671454	4.215143
Epcc	320	593.7344	1034.618	30.09566	4903.905
Gdpc	320	1992.113	2431.662	150.4214	11530.15
SWI	320	-411.613	314.0245	-921.034	.9747136

Source : Author.

Table 2, which presents the correlation matrix, shows that there is a correlation between diversification of energy sources and quality of life.

Table 2. Correlation matrix

	EPCC	FDI	GDPC	RD	SWI	QOL
EPCC	1.000000					
FDI	-0.117295	1.000000				
GDPC	0.734660	-0.039985	1.000000			
RD	0.356300	-0.366902	0.215136	1.000000		
SWI	0.196829	-0.316483	0.180643	0.111371	1.000000	
QOL	-0.111880	-0.061667	-0.024148	-0.151375	0.599613	1.000000

Source : Author

Several techniques were used for the estimation: the random effect method (ROE), the least squares method on stacked data (PLS), and the generalized method of moments on dynamic panel (GMM). From premium on board, we proceeded by the Principal Component Analysis (PCA) method in order to constitute a synthetic indicator, based on the four indicators (life expectancy, mortality rate of children at birth from 0 to 1 year, access to drinking water and schooling rate) which expresses the quality of life (Meadows et al., 2004 and the Economist Intelligence Unit (EIU), 2007). Subsequently, the estimation by the different techniques and the robustness test using the PLS estimator were limited only to short-term effects.

4. PRESENTATION AND ANALYSIS OF RESULTS

The presentation of the results is done in several stages. First, we present the results obtained from the Principal Component Analysis (PCA) study in order to synthesize the quality-of-life variable. Next, we present the results of estimates by the BR, PLS and GMM that capture the impact of energy diversification on quality of life and the results of the robustness test.

4.1. Principal Component Analysis (PCA)

The purpose of using this calculation method is to provide a synthetic indicator to analyse how this index reacts to energy diversification and income factors. Table 3 presents the eigen values that are the first results.

Table 3: Summary of own values

Component	Eigen value	Difference	Proportion	Cumulative
Comp1	2.77189	2.18832	0.6930	0.6930
Comp2	.583577	.103577	0.1459	0.8389
Comp3	.48	.315469	0.1200	0.9589
Comp4	.164531		0.0411	1.0000

Source:Author.

From the table above, the first component (which is life expectancy), offers the best combination (i.e. 0.693) insofar as it explains most variables constituting our future synthetic indicator.

Table 4: Eigenvectors

Variables	Comp1	Comp2	Comp3	Comp4
EWL	.8316	.3695	-.3636	.1992
IWA	.7769	-.6093	.04297	.153
IMR	-.9291	.04964	.182	.3182
EDUC	.7833	.2709	.5593	.01418

Source: Author.

The table above represents the relative proportion of each indicator in the synthetic quality of life index. We are only interested in the selected (Comp1).

Table 5: Ordinary correlations

Variables	EWL	IWA	IMR	EDUC
EWL	10000			
IWA	0.2117	10000		
IMR	0.6037	0.5771	1.0000	
EDUC	-0.1950	-0.1200	0.2146	10000

Source: Author.

In the final phase, we proceed to the KMO test which reflects the inter-correlation between the variables and consequently the performance of the PCA usage. For this test to be acceptable, the measurement must be greater than 0.7101, but the value found in our case is 0.8316, hence the PCA and consequently, the constitution of a composite indicator from these four indicators is recommended in our case study.

4.2. Model estimation by the BR, PLS and GMM methods

The results obtained show a positive and significant 1% short-term effect of diversification of energy sources and quality of life (Table 6) in the different estimates. The latter assumes that diversification of energy sources plays a key role in quality of life. Diversification of energy sources is a factor in the security of energy supply and respect for the environment. It is essential for a sustained quality of life and poverty reduction in the development of economic activity through quantitative improvement: increased life expectancy and improved health of the population; and qualitative improvement or better training of the workforce. As the diversification of energy sources increases, so does technological innovation in energy production. This result is consistent with the authors' work (Rosenberg, 2008; Ross, 2014). It is noted that these results support the hypothesis that energy diversification has a positive and significant impact on quality of life. Indeed, as countries develop, the level of per capita income increases and leads to the choice of investments in electricity markets as a risk hedge. This increase in income can be put, without risk, in the development of the quality of the environment to accompany large-scale projects of energy diversification.

Table. 6: Summary of Estimation Results.

VARIABLES	(RE) qol	(PLS) qol	(GMM) qol
GDPC	0.915***	0.707***	0.839***
	(0.0734)	(0.128)	(0.0168)
EPCC	0.290**	0.332***	0.108***
	(0.138)	(0.103)	(0.0167)
SWI	0.124***	0.0968***	0.110***
	(0.0176)	(0.0203)	(0.00523)
Constant	-7.493***	-6.381***	-6.014***
	(0.635)	(0.504)	(0.0870)
Comments	320	320	320
AR1 (prob)			0.593
AR2 (prob)			0.126
R-squared		0.490	
Number of code	20		20

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author.

4.3. Robustness test

To assess the stability of our results, we segment the model to be estimated from our sample into three periods: 2000-2005, 2006-2010 and 2011-2015. < Table 7 > presents the results obtained :

Table 7: Robustness Test Results

VARIABLES	**(2000-2005)** **qol**	**(2006-2010)** **qol**	**(2011-2015)** **qol**
logGDPC	1.001***	0.553***	0.162***
	(0.175)	(0.170)	(0.171)
logEPCC	0.223*	0.359**	0.595***
	(0.133)	(0.143)	(0.147)
Swi	0.0582*	0.110***	0.122***
	(0.0330)	(0.0403)	(0.0407)
Constant	-8.120***	-5.406***	-3.437***
	(0.797)	(0.897)	(0.894)
Comments	120	100	100
R-squared	0.533	0.428	0.398

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author.

In summary, the robustness analysis allows us to conclude that our results are not weakened. Moreover, the results are unchanged with respect to the reduction in the sample period and other regression variables. This same analysis of the robustness test shows that the trend in the impact of energy diversification on quality of life is positive and significant overall at 1% and 10% respectively. This study helps in understanding the crucial role of energy in socio-economic development. Access to reliable, clean energy can improve education, health and environmental conditions in developing countries, and especially in rural areas.

5. CONCLUSION

The empirical study conducted in this article allowed us to analyse the effect of energy diversification on the quality of life in SSA. Using several regression techniques - BR, PLS and GMM - the results show that there is a short-term effect between energy diversification and the quality of life in SSA. This finding allows us to assess the role of energy diversification on the quality of life. The challenge of energy diversification for well-being is not in determining the long-term sustainable state, but rather in the process of transition to that state. Thus, in the long term, even though we will have much less energy to consume, we can expect a very pleasant level of quality of life. From these results, it is worth mentioning that the existence of the short-term relationship between diversification of energy sources and quality of life in SSA suggests the need for education within SSA countries and economic policy recommendations, as the difficulty of access to energy is a hindrance to development. The positive impact of the diversification of energy sources on the quality of life of the population has a direct effect on the development of economic activity through quantitative (increased life expectancy and improved health of the population) and qualitative (better training of the workforce) improvements. As recommendations for economic policy, the States of SSA countries should seek their own structural changes that can promote balanced economic, environmental and social development with less energy from fossil fuels; give priority to better exploitation of the most abundant, clean, profitable and locally present energy sources, i.e. renewable energies; promote the policy of electrification of rural areas with the aim of benefiting the agricultural sector and the population (reduction of rural exodus). Moreover, this policy of decentralization of electricity production in rural areas will create jobs including lower unemployment, improved health and longer hours of study for better performance in education (Shumacher, 1973). So, for a good energy policy, according to the International Energy Agency, it is necessary to be characterized by the three pillars of the "3E" energy balance: *Energy Security, Economic growth, Environmental protection,* because none of these elements cannot be neglected without compromising the whole.

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