Effect of Financial Development on Energy Diversification in Sub-Saharan Africa

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1. INTRODUCTION

Financial development and diversification of energy sources are general themes but are becoming increasing concerns with regard to the current situation in developing countries and particularly in Sub-Saharan Africa. On the one hand, on the financing of energy projects and on the other hand, on the difficulties of access to energy. In Sub-Saharan Africa, a person on three has access to energy1 and her population lives in

ABSTRACT

The objective of this paper is to analyse the effect of financial development on energy diversification in 20 sub-Saharan African countries between 2000 and 2015. Our specificity is the calculation of the energy diversification index using the Shannon Wiener index (Stirling 1998-2000) and the estimation using the generalized moments method (GMM) on a dynamic panel. The results show that financial development positively and significantly affects the diversification of energy sources. Thus, these countries need to improve their financial systems to promote energy sources diversification to improve access to energy and improve the process of financing energy projects as a response to poverty reduction.

Keywords: Financial development; Energy diversification; Shannon Wiener Index; MMG; panel data.
a system of concentration in power consumption, in spite of her wealth in fossil and renewable energies. This energy paradox raises questions. The diversification of energy sources is one such question. Studying the diversification of energy sources turns to be determinant for several reasons: it ensures the security of energy supply and makes it possible to meet up with different risks, (Stirling, 1999) [1,2].

Diversification of energy sources is derived from the energy that is necessary for socio-economic development, [3]. Its consumption cannot be without effect, thus raising some questions. These questions have become planetary and the whole world is mobilizing through several channels to find adequate answers: the research for technological innovation, capital accumulation, investments, awareness raising, international summits on the environment. Historically, these questions on the energy problem date back to the work of the neoclassicals. Stanley Jevons (1865) is the one who approved it towards the charcoal stocks depletion, especially as consumption is increasing. Percebois 1978 [4], based on the myth of energy saving, shows that social progress is linked to the quantity of energy consumed. Schumpeter (1912), [5] on his part emphasizes the primary role of bankers, who, by targeting and financing entrepreneurs, encourage technological innovation and capital accumulation and thus stimulate economic growth. Thus, financial development stimulates growth by increasing the rate of investment, allocating capital to the most productive projects such as the energy sources diversification, because one cannot transform input into output without consuming energy. Therefore, this study asks the following question: What is the effect of financial development on energy diversification in SSA?

There are many studies to date that have looked at the effect of financial development on energy sources diversification [6], Martinez, 1989; Fabien Roques 2005; and McKinsey, Castellano et al., 2015). Very few studies have focused on SSA. We can mention the work of Keramane (2010) which states that a fully integrated electricity market can save African countries $2 billion in terms of annual operating and grid development costs. Avadikyan and Mainguy 2016 [7] provide a theoretical overview of the role of finance in energy projects in SSA. They conclude that diversification of energy sources is the exit solution to energy scarcity and an essential condition for socio-economic and human development in SSA.

Taking all these facts into account, this study assesses the effect between financial development and energy diversification in SSA. In order to overcome the problems mentioned in the above literature, this study uses the Generalized Moments Method on Dynamic Panel (GMM) which takes into account the heterogeneity between the variables. The paper shows that there is an effect of financial development on the diversification of energy sources.

The rest of this paper is organized into three additional sections. The first section presents the literature, the second one presents the stylized facts and methodological approach, and the third one presents and discusses the results.

2. FINANCIAL DEVELOPMENT AND DIVERSIFICATION OF ENERGY SOURCES: A SYNTHESIS OF THE STATE OF THE ART

2.1 A Theoretical Synthesis

Any economy without money is inefficient, that is why the monetarization of economies is in the primary stage of development. Through this role in development, we present its effect between financial development and diversification of energy sources. Schumpeter (1912) had emphasized the primordial role of bankers, who through their targeting and financing of entrepreneurs, encourage technological innovation, capital accumulation and thus stimulate economic growth. Thus, financial development stimulates growth by increasing the rate of investment, allocating capital to the most productive projects such as the diversification of energy sources, because one cannot transform input into output without consuming energy. To reach this end, financial intermediaries perform five main functions identified by Levine (1997, 2004). There are several theoretical models on the relationship between financial development and diversification of energy sources. The one that examines a relationship with diversification of energy sources is the King and Levine (1993b) model. King and Levine (1993b) examine the role of the financial system in mobilizing savings and financing innovative projects. As mentioned

of the 915 million inhabitants have access to electricity (IEA [8], IRENA 2013 [9]).
earlier, Stanley Jevons (1865) in his work, marked the real introduction of the energy issue into economic analysis. The analysis of the place of energy in economic theory highlights that of the diversification of energy sources that emanates from technological progress in energy. The diversification of energy sources is in line with neoclassical thinking and involves learning by doing developed by Arrow (1962) and technological innovation, (Rosenberg, 1982; Guelllec, 1999; Aghion and Howitt, 2000 [10]). Diversifying energy sources is a process that ensures the security of supply of electrical energy and coping with possible risks, Stirling (1998 and 2001; Artigues, [11]).

Assessing the effect of financial development on energy diversification is similar to the relationship between finance and energy (Agbetsiafa, 2004 [12], Sadorsky, 2010; Chitioui, 2012; Shahbaz and Lean, 2012; Al-Mulali and Sab, 2012b) [13]. It is emerging as one of the powerful mechanisms of socio-economic development. Finance clearly remains one of the weaknesses and major constraints in poor economies, particularly in sub-Saharan Africa. Financial development first leads to look for the underlying factors in order to be able to set up a policy for the development of the financial system. One is then led to question which factors condition financial development, and indirectly which financial provisions or policies in terms of finance can promote the diversification of energy sources. A formal approach based on the rules of law and their application and another based on social and cultural factors will make it possible to decide on the determining factors of financial development. As a determinant of the financial development, we mention: The legal and institutional approach, (La Porta et al., 2005); the ideological and social approach, (Acemoglu and Robinson, 2001; Levine and Beck, 2003; Pagano and Volpin, 2001; Nissanke and Aryeetey, 2006; Guha-Khasnobis, Kanbur and Ostrom, 2005). Further to these determinants, financial development in the exercise of its various functions presents indicators that are: the monetary aggregate M2 as a share of GDP, the assets of commercial banks divided by the total assets of commercial banks and the central bank, the share of credit to the private sector in total domestic credit and the share of credit to the private sector in GDP....

From this consideration of finance and energy, we have the studies that decisively seal the link between energy and modern economic development (Fouquet 2008; Ayres 2009). Carbonnier and Grinevald (2011) [14] point out that development has an effect on energy by tracing the importance of fossil fuels in economic growth. They present the stakes of a financial system on energy development. By setting the milestone for access to financing and exploitation of resources, this argument is supported in the studies conducted by Martinez (1989). For Martinez (1989) [6], the policy of diversification of energy sources is a factor that could increase the rate of economic growth and financial development for a good energy transition.

Avadiykan and Mainguy [7] in their analysis of the energy situation in Sub-Saharan Africa propose first of all that diversification of energy sources is the solution that can alleviate the difficulties of access to energy and then, that diversification of energy sources can be done through large investments to finance energy projects which are based on the mechanisms of credit systems very often.

2.2 An Empirical Synthesis

Works on finance and energy follow a particular methodology. Authors use either time series or panel data to explore the link between the two concepts which constitute their points of reflection through the Auto Regressive Distributed Lag (ARDL) method, Generalized Moments method (GMM), ... In these studies, several determinants of financial development were used. We can mention the domestic credit granted to the private sector in the works of (Shahbaz et al., 2013 [15]; Doaa and Eyad, 2014 [16], Yusop et al., 2015 [17]; Hamisu, 2015 and Duk et al. 2017). [18]. A main component analysis of domestic credit to the private sector, domestic credit provided by the financial sector, domestic credit to the private sector by banks, and money and quasi-money in the studies of (Kassi et al., 2017) [19].

From the work on financial development and diversification of energy sources we refer to authors such as:

Manuel Martinez (2000) conducts a study on Priority Energy Diversification for the Power Sector in Mexico. Using the net present value method, Martinez arrives at the result that financial development influences the diversification of energy sources via geothermal, hydroelectric, charcoal is technically and economically viable.

Ross (2014) [20], who conducts an analytical study on Asia, shows that energy diversification
is like a forecast. He examines the future status of the prospects, environmental implications, investment and infrastructure requirements and risks of alternative energy sources such as solar, wind, and unconventional gas. The results show that diversifying energy sources has a positive impact on investment through the provision of credit and on the environment in terms of wind and photovoltaic power generation. There is a restriction of CO2 and GHG emissions.

Shahriyar Nasirov and Carlos Silva (2014) conduct a study on the diversification of the energy matrix. From this work, they show that Chile faces high energy prices and a critical lack of investment in the sector. To this effect, in order to highlight the diversification of the energy matrix, the financial system and strategically important energy alternatives under consideration for Chile are studied, including developing clean energy sources through Renewable Energy Technologies, energy efficiency, traditional energy sources (coal and LNG), and the nuclear energy option.

Duk et al., (2017) [18] examined the effect of energy diversification in 15 OECD countries on annual data between 1984 and 2010. Using the multivariate method and the generalised moments method, the results show a positive effect of financial development on energy diversification on oil price changes and economic growth.

3. STYLIZED FACTS AND EMPIRICAL MODEL

First we present the stylized facts and then the empirical approach.

3.1 Stylized Facts

The diversification of energy sources through renewable energy in SSA shows an evolving trend that varies from country to country. In 2011, renewable energy sources accounted for 16.7% of global final energy consumption (out of this total, the share of renewable energy is estimated at 8.2% against only 8.5% for traditional biomass, which is in slight decline) (AFD and AfDB, 2009 [21]). During the same year, renewable energy continued to grow strongly in all sectors of final consumption: electricity, heating and cooling, and transport2.

The following Graph 1 shows its evolution from 2000 to 2015.

Graph 1 shows the evolution of the energy diversification index over the period 2000-2015. Looking at the graph on the evolution of the SWI, we note that Nigeria, South Africa, Benin, Niger, Senegal and Angola are more diversified than other SSA countries that are booming in energy diversification and others such as Mozambique for example that are either stagnant. According to the theory a high value of this index indicates more diversification, (Grubb et al., 2006).

Regarding financial development, Graph 2 below shows that in SSA there has been an increase in the number of way to oscillate. In South Africa there is a high DFI which reflects the good health of the financial system in South Africa. As well as in Angola, Mauritius, Namibia, Sudan and Zimbabwe. And in other countries the DFI is low, which justifies the poor health of the financial system in these countries. Subdividing SSA into four: West Africa, East Africa, Central Africa and Southern Africa. We note that the countries with a perfectly healthy financial system are the countries of Southern Africa (South Africa, Namibia and Zimbabwe) and East Africa (Angola, Mauritius and Sudan). It can be concluded that in Central and West Africa the financial system is in need of improvement.

As regards the correlation between financial development and diversification of energy sources, the overall trend shows a positive correlation between the two concepts: the more a country is diversified in energy, the more it has excellent financial development. In this figure we have Nigeria, Niger, Benin, Senegal, Kenya, South Africa and Mauritius which have an energy diversification index that tends towards 0 or equal to zero, thus good energy diversification and increasing financial development. Graph 3 below represents this correlation.

3.2 Study Data and Methodology

Data and variable measures: The sample of our study covers 20 countries in Sub-Saharan Africa3. Data were used for the period 2000-2015. They are annual in logarithmic form and are obtained from the World Bank’s World Development Indicators (WDI) 2016 database.

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2David Vilar Ferrenbach et al. Report on Renewable Energy in West Africa, 2012.

3The countries included in the sample are: Angola, Benin, Cameroon, Democratic Republic of Congo, Congo, Côte d’Ivoire, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Nigeria, Niger, Senegal, South Africa, Sudan, Tanzania, Togo and Zimbabwe.
Graph 1. Evolution of Energy Diversification in SSA over the 2000-2015 Period
Source: Estimated by the author based on WDI

Graph 2. Evolution of financial development in SSA over the 2000-2015 period
Source: Estimated by the author based on WDI

Graph 3. Cross trends in financial development and energy diversification in SSA 2000-2015
Source: Estimated by the author based on WDI
In the study, several variables were used to analyse the influence of energy diversification on financial development.

First of all, we determine the energy diversification index which is materialized by the Shannon Wiener Index (SWI) as developed by (Stirling,1998-2001), [1,2]. Stirling uses diversity as a concept with three subordinates: variety, equity and disparity.

- Variety is a positive integer measuring the number of categories in which different primary energy sources are classified, the greater the variety, the greater the energy diversity.
- Balance is a concept measuring the homogeneity of the relative proportions of the different primary energy sources.
- Disparity refers to the nature of the categories of primary energy sources and measures the degree of differentiation between categories. 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. The greater these three components, the higher the diversity index. Stirling shows that traditional economic indicators of concentration such as the Herfindahl-Hirschman Index do not capture these three components of a diverse system. He recommends the use of the Shannon-Wiener index.

This energy diversification index, defined above, is highlighted by Stirling’s (1999) work. Stirling uses the general form of Hill’s biodiversity index⁴, taking into account variety and balance:

\[ \Delta_a = \sum_i \left( p_i^a \right)^{1/(1-a)} \]

While putting \( a=1 \) then \( a=2 \), one gets The Shannon-Wiener Index (SWI), noted \( \Delta_1 \), and the Herfindahl-Hirschman Concentration Index (HHI) used in economics, noted \( \Delta_2 \):

\[ \Delta_1 = -\sum_i \ln p_i \quad \text{And} \quad \Delta_2 = 1/\sum_i p_i^2 \]

It is these indices that are most commonly used in the energy literature⁵.

The HHI is a commonly accepted measure of market concentration, which takes into account the total number of firms in the market and their relative size (market share). To apply the HHI to energy markets, the variable "firm market share" is simply replaced by the "percentage of energy imports from a particular country".

The question of the relevance of one indicator to another arises in the literature. Grubb et al. (2005) show that in general the results of the HHI are consistent with those obtained from the SWI. According to Stirling (1999) [2], the Shannon index is to be preferred for different reasons⁶, related to the mathematical form of the two indices⁷.

The Shannon-Wiener Diversity Index \( \Delta_{\text{ener}} \), illustrates the Energy Diversification Index, calculated for the primary energy portfolio, which is:

\[ \Delta_{\text{ener}} = -\sum_i c_i p_i \ln p_i \quad \text{In this expression,} \quad p_i \quad \text{represents the share of primary} \quad i \quad \text{in the} \quad \text{total primary energy sources, with} \quad i = 1, ..., M \quad (M \quad \text{being the number of energy sources)}. \quad c_i \quad \text{is a} \quad \text{correction factor of} \quad p_i \quad \text{for the indicator} \quad \Delta_{\text{ener}}, \quad \text{equal to the unit for this first indicator.} \quad \text{The} \quad \text{minimum value of} \quad \Delta_{\text{ener}} \quad \text{is} \quad 0 \quad \text{in the case where all energy production is concentrated on a single primary energy source. The upper value in the opposite case depending on the primary energy category (e.g. coal, gas, oil, etc.). Consequently, a low value} \quad \Delta_{\text{ener}} \quad \text{indicates an unfavourable situation in terms of energy diversity compared to a high value of this indicator.}

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⁴ Hill, M.O. (1973), "Diversité et uniformité : une notation unificatrice et ses conséquences", Ecologie, 54, 427-431
⁵ Stirling was interested in the possibility of capturing the different dimensions of diversity using a simple and robust quantitative indicator. He shows that it is difficult to define an indicator that captures the complex and fundamentally subjective concept of disparity. He proposes a multi-criteria diversity index that, in his view, has the three properties of variety, balance and disparity. However, according to Jansen et al. (2004), this index is complex and subject to methodological restrictions that make diversity a "complex" concept. Generally analyzed using the HHI and SWI index.
⁶ Grubb et al. (2005) point out that the White Paper used an approach similar to Stirling’s to demonstrate that in recent decades, the British electricity system has become more diverse
⁷ One of the reasons given is that changing the base of the logarithms used in the Shannon Index-Wiener is not likely to change the ranking between different systems.
Table 1. Description and source of variables

| Variables                             | Symbol | Definition                                                                 | Data source |
|---------------------------------------|--------|-----------------------------------------------------------------------------|-------------|
| Financial Development                 | DFI    | Materialized by domestic credit to the private sector measured as a percentage of GDP. | World Development Indicators$^8$ |
| Energy Consumption Income             | EPCC, GDPC | Electricity consumption rate (Kwh per capital) and income per capita (GDPC) expressed in constant dollars/hbt | WDI         |
| Trade openness                        | TRADE  | Trade openness (% GDP)                                                      | WDI         |
| Total energy consumption rates        | TCER   | The total energy consumption rate                                           | WDI         |
| Consumption of energy from oil        | EPOC   | The rate of consumption of petroleum-based energy products                  | WDI         |
| Energy Diversification Index          | SWI    | Shannon Wiener Index (SWI)                                                  | WDI         |

Source: Done by the author

Operationally, we used all renewable energy sources to calculate the Energy Diversification Index for all the sub-Saharan African countries in our sample.

Table 1 gives the definition and source of the variables used.

**Methodology:** The analysis model used is based on those used in the studies by Duk et al., (2017) [18]. The estimation model is as follows:

$$DFI_{it} = f\left(A, EPCC_{it}, GDPC_{it}, TRADE_{it}, TCER_{it}, EPOC_{it}, SWI_{it}\right)$$  \hspace{1cm} (1)

$$Y_{it} = x_{it} \beta_i + \mu_{it}$$

Avec $x_{it}$

$$x_{it} = \alpha_{2i} + \theta_i \delta_i + \lambda_i \varepsilon_i$$

Note that $Y_{it}$ represents the endogenous variable (DFI) which is materialized by domestic credit to the private sector of country $i$ ($i=1,2,...,N$) in year $t$ ($t=1,2,...,T$). Are included in $x_{it}$ the set of exogenous variables (EPCC, GDPC, TRADE, TCER, EPOC and SWI).

Specifically we have the following regression model:

$$LNDFI_{it} = \alpha_i + \delta_i t + \beta_1 LN\text{EPCC}_{it} + \beta_2 LN\text{GDPC}_{it} + \beta_3 LN\text{TRADE}_{it} + \beta_4 LN\text{TCER}_{it} + \beta_5 LN\text{EPOC}_{it} + \beta_6 LN\text{SWI}_{it} + \varepsilon_{it}$$  \hspace{1cm} (2)

With $\alpha_i$ fixed effects, $\delta_i$ is the trend coefficient, $\beta_1, \ldots, \beta_6$ are the regression coefficients, term of $\varepsilon_{it}$ the error. The set of variables is defined in Table 1. We begin our estimates with the unit root tests as developed by Levin, Lin and Chu (LLC, 1992) and Im Pesaran and Shin (IPS, 2003) and then estimate our study model using the Generalized Moment Method on a dynamic panel (Arellano and Bover, 1995).

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$^8$ World Development Indicator, 2016. http://data.worldbank.org/products/wdi.
4. RESULTS ANALYSIS AND DISCUSSION

We first present the results of the unit root tests in Table 2 and then the results of the econometric estimates in Table 3.

4.1 Unit-root Test

In order to apply the estimation it is essential to assess the stationarity of the series and the order of integration of the variables. The results of these tests are presented in Table 2.

The results of the unit root tests indicate that the variables: income, financial development and the energy diversification index are integrated in I (1) and not stationary. And the variables: rate of electricity consumption, rate of renewable energy consumption, rate of consumption of petroleum-based energy and trade openness are integrated in I (0) and stationary. All these variables respectively are significant at 5%.

Based on the results of the unit root panel tests obtained, they show that the variables are stationary and integrated at level (0) and first difference (1).

4.2 Estimation by the GMM Method

Table 3 presents the results of estimating the effect of energy diversification on financial development in Sub-Saharan Africa.

Table 3 presents the results of the estimation by the generalized method of moments of the effect of financial development on the diversification of energy sources. These results show that the signs of the variable coefficients are as expected: An increase in financial development will lead to an increase in the diversification of energy sources. As for electricity consumption, its coefficient is positive. This means that the more efficient the production of electricity is, the more energy consumption increases. Similarly for trade openness, it has a positive coefficient, which means an increase in trade in energy from the more energy-rich countries to those with little or no capacity. The negative coefficient associated with the rate of consumption of oil-

| Variables | Test de LLC sans constant | Test d’IPS sans constant (Integration sequence) | Stationarity decision |
|-----------|---------------------------|-----------------------------------------------|----------------------|
| GDPC      | 0.0581                    | 0.8864                                        | I(1) NO              |
| EPCC      | 0.0001                    | 0.6896                                        | I(0) YES             |
| DFI       | 0.8985                    | 0.9993                                        | I(1) NO              |
| TCER      | 0.0000                    | 0.4140                                        | I(0) YES             |
| SWI       | 0.8373                    | 0.9847                                        | I(1) NO              |
| EPOC      | 0.5705                    | 0.0008                                        | I(0) YES             |
| TRADE     | 0.0001                    | 0.0359                                        | I(0) YES             |

Note: (**) indicate significance levels at 5% respectively. Source: Estimated by the author.

| Variables | Coef   | Std.Err | Z     | P-value |
|-----------|--------|---------|-------|---------|
| DFI       |        |         |       |         |
| L1.       | .4999***| .0409   | 12.21 | 0.000   |
| EPCC      | .0083***| .0019   | 4.23  | 0.000   |
| GDPC      | -.0001* | .0004   | -0.35 | 0.726   |
| TRADE     | .0723** | .0356   | 2.03  | 0.042   |
| TCER      | -.5020***| .0982 | -5.11 | 0.000   |
| EPOC      | -.1480***| .0640 | -2.31 | 0.021   |
| SWI       | .0103***| .0034   | 2.98  | 0.003   |
| Cons      | 44.18***| 9.928   | 4.45  | 0.000   |
| Observations | 320 |         |       |         |
| AR1 (prob) | 0.593 |         |       |         |
| AR2 (prob) | 0.126 |         |       |         |

***, **, * indicate significance levels at the 1%, 5% and 10% thresholds respectively. Source: Estimated by the author.
based energy underscores the fact that diversification of energy sources facilitates better environmental performance (Rouhier, 2010 [22]). With regard to per capita income, although the coefficient is negative, it is significant at 10% and this does not affect our results.

Overall, this model is positive and significant at 1%, which corroborates the idea developed that emphasizing financial development (in the electricity sector in particular) will have positive results on the diversification of energy sources. These results are consistent with those of Manuel Martinez (2000), Ross (2014) [20] and Duk et al., (2017) [18]. In view of these results, our hypothesis is confirmed, financial development has a positive and significant impact on the diversification of energy sources.

The main limitations of this model are the choice of indicators. Indeed, another way of defining the diversification of energy sources could have been chosen.

5. CONCLUSION

The objective of this paper is to analyse the effect of financial development on the diversification of energy sources in Sub-Saharan Africa for the period 2000-2015. The results of the unit root tests of Levin, Lin and Chu (1992) and Im, Pesaran, Shin (2003) show that the variables are stationary and integrated at level (0) and first difference (1), significant at 5%. The results of Arellano and Bover’s (1995) Generalized Moments Method (GMM) estimation indicate that there is a positive and significant 1% influence between financial development and diversification of energy sources globally.

From these results, it should be pointed out that it can be a two-way meaning because a developed financial system allows for better investment. We can conclude that the diversification of energy sources via renewable energies as any other energy influences the macroeconomic variables (GDP, financial development, trade opening, unemployment, ...) because most of the macroeconomic variables depend on the GDP. Diversification of energy sources allows the improvement and security of energy supply. It can therefore be mentioned that the policy aimed at diversifying energy sources should be encouraged in order to reduce difficulties of access to energy, reduce pollution and promote more investment in energy projects as it constitutes an alternative response to traditional energy (oil) and poverty reduction.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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