Financing the alternative: renewable energy in the Nigerian economy

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Abstract: Achieving a diversified and sustainable energy supply for future generations is one of the major challenges for today's policy makers. The feat of the sustainable energy supply requires diversifying energy sources and changing the current dependence on non-renewable and polluting hydrocarbons fuels. This paper examines the role of the financial sector in renewable energy (RE) development in Nigeria. Notwithstanding, RE brings socio-economic and environmental benefits, however, its implementation encounters a number of impediments, especially in Nigeria. One of these impediments is financing: underdeveloped financial sectors are unable to efficiently channel loans to RE energy fabricators. The impact of financial sector development on the use of renewable energy resources is inveterated in dynamic generalised method of moment (GMM) estimations on Nigeria for 1980 to 2008. Financial intermediation, especially commercial banking, has a significant positive effect on the quantity of RE produced, and the impact is remarkably large when we consider non-hydropower RE such as solar, geothermal and biomass. The results of the dynamic GMM estimations are very suggestive of a robust impact of financial sector development-especially commercial bank asset share and private credit share on RE production in Nigeria.

Keywords: renewable energy; generalised method of moment; GMM; commercial bank; financial intermediation; Nigeria.

Reference to this paper should be made as follows: Omojolaibi, J.A. (2016) 'Financing the alternative: renewable energy in the Nigerian economy', *Int. J. Environment and Sustainable Development*, Vol. 15, No. 2, pp.183–200.

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1 Introduction

Achieving a diversified and sustainable energy supply for future generations is one of the major challenges for today's policy makers. Global energy demand is projected to grow by around 45% by 2030 (Brunnschweiler, 2010a). More than three-quarters of the increased demand will come from developing and transition countries (IEA, 2008). Energy demand will continue to be covered mainly by conventional fossil fuels, such as coal, oil and natural gas; accordingly, energy-related pollution is predicted to increase by up to 45%. Although Organization for Economic Cooperation and Development (OECD) countries will still be major polluters, 97% of the estimated increase will come from non-OECD countries (IEA, 2008).

Meanwhile, many estimates predict that oil and possibly natural gas production will plateau around the same time, casting doubt on future energy security. Hence, achieving a sustainable energy supply requires diversifying energy sources and changing the current dependence on non-renewable and polluting hydrocarbon fuels. For example, in a recent report, the UN Commission on Sustainable Development states:

> "Energy is crucial for sustainable development, poverty eradication and achieving the internationally agreed development goals, including the Millennium Development Goals. [...J. Access to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services is crucial, particularly in developing countries. […1 While fossil fuels will continue to play an important role in the energy supply in the decades to come, every effort must be made to diversify the energy mix." [UN Commission on Sustainable Development, (2007), p.15]

Renewable energy technologies (RETs) can bring about both environmental and socio-economic benefits.[1] They generally entail fewer emissions, use local resources – including labour, foster basic electrification in developing countries, including Nigeria and increase energy security.[2] However, although there are already several commercially available and economically attractive RETs, they still account for only a modest proportion of global energy generation. This fact suggests that there are some missing links between the potential of RETs and their implementation.

The primary focus of this study is on one important missing link: the financing of renewable energy (RE) projects, in particular, the relationship between financial sector (commercial banks) and RET development in Nigeria. The study uses annual data on Nigeria covering the time span 1980 to 2008. This missing link has been pointed out by numerous studies and practitioners, who see the absence of well-developed financial intermediaries and the consequent financing difficulties as one of the most important obstacles during the realisation of RE projects in Nigeria.

Energy projects generally demand high levels of financing, which fabricators in Nigeria in particular can rarely cover on their own. In turn, the financing for RETs is closely connected to the development of the financial sector. RE projects have very high start-up costs relative to the expected monetary returns, and lengthy payback periods: they therefore typically require long-term maturity loans (UNEP FI, 2004; Sonntag-O'Brien and Usher, 2004).

The problem of financing RE project is twofold: first, RET firms generally need long-term loans, whose availability in turn is positively linked to the development of the banking system (Demiriguc-Kunt and Maksimovic, 1999). In Nigeria, the banking sector is the major source of external financing (Tadesse, 2002), and access to bank credit is a serious problem especially for small- and medium-sized companies (Beck et al., 2004). As a consequence, RE projects in Nigeria are at a particular disadvantage. Second, RET firms have limited access to financing because RE projects compete against fossil fuel projects, which have a longer track record, relatively lower up-front costs, shorter lead times, and often favourable political treatment (Churchill and Saunders, 1989; World Bank, 2002; Sonntag-O'Brien and Usher, 2004).

It is worth noting that in both cases, underinvestment in RET firms can be interpreted in terms of imperfect information between firms and financiers: projects aimed at developing new technologies bear, almost by definition, greater information costs to investors, which are more easily borne by a highly developed financial sector. Where the latter is not given, the result may well be a market distortion in favour of less risky investments, such as fossil fuel projects and large-sized enterprises. This is consistent with the view that the development of the domestic financial sector is a crucial factor in meeting the booming energy demand in developing and transition economies (Ishiguro and Akiyama, 1995; World Bank, 2003).

Despite the importance of the financial sector for the development of RETs particularly in developing and transition countries, which is borne out by numerous case studies and anecdotal evidence, the subject has received little academic/empirical research attention especially in Africa, hence, the need for this country specific study. This paper contributes to the knowledge on what determines RET implementation by empirically analysing the relationship between financial intermediation and RE sector development, with a focus on Nigeria. To the best of our knowledge, this is one of the foremost attempts to examine this issue in Nigeria in a systematic empirical analysis.[3]

2 Background of the study: RE resource availability in Nigeria[4]

For the purpose of this study, the RE sources that will be considered are hydro, solar energy, biomass and wind energy.

- Hydro

  Essentially, hydropower systems rely on the potential energy difference between the levels of water in reservoirs, dams or lakes and their discharge tail water levels downstream. The water turbines which convert the potential energy of water to shaft rotation are coupled to suitable generators. The hydropower potential of Nigeria is very high and hydropower currently accounts for about 29% of the total electrical power supply (Sambo, 2005). The first hydropower supply station in Nigeria is at Kainji on the river Niger where the installed capacity is 836 MW with provisions for expansion to 1,156 MW. A second hydropower station on the Niger is at Jebba with an installed capacity of 540 MW. An estimate for rivers Kaduna, Benue and Cross River at Shiroro, Makurdi and Ikom, respectively indicates their total capacity stand at about 4,650 MW. Estimates for the rivers on the Mambila Plateau are put at 2,330 MW. The overall hydropower resources potentially exploitable in Nigeria are

in excess of 11,000 MW (Sambo, 2005). The foregoing assessment is for large hydro schemes which have predominantly been the class of schemes in use prior to the oil crisis of 1973. Indeed, small-scale hydropower systems possess the advantage, over large hydro systems, in effect, small hydropower systems can be setup in all parts of the country so that the potential energy in the large network of rivers can be tapped and converted to electrical energy. In this way, the nation's rural electrification projects can be greatly enhanced.

- Solar energy

  Solar energy is the most promising of the RE sources in view of its apparent limitless potential (Folayan, 1988). The sun radiates its energy at the rate of about 3.8 × 1,023 kW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5 kW/m^5 at the boundary of the atmosphere (Painuly, 2006). After traversing the atmosphere, a square metre of the earth's surface can receive as much as 1 kW of solar power, averaging to about 0.5 over all hours of daylight.[5] Although solar radiation intensity appears rather dilute when compared with the volumetric concentration of energy in fossil fuels, it has been confirmed that Nigeria receives 5.08 × 1,012 kWh of energy per day from the sun and if solar energy appliances with just 5% efficiency are used to cover only 1% of the country's surface area then 2.54 × 106 MWh of electrical energy can be obtained from solar energy. This amount of electrical energy is equivalent to 4.66 million barrels of oil per day (Sambo, 2005).

- Biomass

  Biomass energy refers to the energy of biological systems such as wood and wastes. Biomass energy is an indirect form of solar energy because it arises due to photosynthesis. The biomass resources of Nigeria can be identified as wood biomass, forage grasses and shrubs, residues and wastes (forestry, agricultural, municipal and industrial) as well as aquatic biomass. Wood, apart from being a major source of energy in the form of fuel-wood is also used for commercial purposes in various forms as plywood, sawn-wood, paper products and electric poles. For energy purposes, Nigeria is using 80 million cubic metres (43.4 × 109 kg) of fuel-wood annually for cooking and other domestic purposes (Sambo, 2005). Although the biomass availability as at 1973 was put at 9.1 × 1,012 MJ, it is expected that the overall biomass resource availability at present is lower than the 1973 figure. This is largely due to the demand of wood also for construction and furniture industries in addition to its use as an energy source. As for forage grasses and shrubs, estimates show that 200 million tonnes of dry biomass can be obtained from them and this comes up to 2.28 × 106 MJ of energy. For crop residues and wastes, estimates of the 6.1 million tonnes of dry biomass that are produced annually leave residues whose energy content approximate to 5.3 × 1,011 MJ (Sambo, 2005).

- Wind energy

  Wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Seasonal variations in the energy received from the sun affect the strength and direction of the wind. The

ease with which aeroturbines transform energy in moving air to rotary mechanical energy suggests the use of electrical devices to convert wind energy to electricity. Wind energy has also been utilised, for decades, for water pumping as well as for the milling of grains. Although the use of wind energy for water supply has been known and used for hundreds of years, in recent times, efforts have been directed largely towards the use of wind power for the generation of electricity and in the past 20 years rapid changes in technology have occurred and major wind powered generating plants have been installed, especially in the rural areas of the developed countries (Sambo, 2005; Omojolaibi, 2009).

2.1 Scenarios for RE: the global fronts

Many scenarios have been developed to illustrate future global demand and supply of energy. A review of these scenarios that explore the future role of RE is presented in Table 1. The year 2050 has been chosen for illustrative purposes, and is a frequently selected year for long-term energy scenarios in the literature. Special attention is given to several sets of scenarios: the Renewables-Intensive Global Energy Scenario (RIGES); the scenarios presented by the International Institute for Applied Systems Analysis (IIASA) and the World Energy Council (WEC); the set of scenarios developed by the Intergovernmental Panel on Climate Change (IPCC); and the Shell Corporation scenarios.

Table 1 shows the total amount of RE and the percentage of RE of the total energy supply. A larger RE share of total energy supply does not necessarily mean a high quantity of RE but depends on the total energy use in the scenario.

The RIGES scenario, which has been described as a renewable-intensive global energy scenario, illustrates the potential markets for RE assuming that market barriers will be removed by comprehensive, and even accelerated, policy measures. In the scenario, it is assumed that RETs will capture markets whenever:

1 RE is no more expensive on a life-cycle cost basis than conventional alternative

2 the use of renewable technologies will not create significant environmental, land use, or other problems.

The analysis does not consider the credits of any external benefits from RE.

The results of the IIASA and WEC scenarios are a bit less optimistic than the RIGES scenario but still present a significant increase in RE by 2050. Furthermore, the scenarios show a span in energy demand, total renewable and share of renewable. In the 'ecologically driven scenario', which also describes the results of ambitious policy measures to accelerate energy efficiency and RETs, RE accounts for 40% of the energy demand by 2050 of which approximately 30% is biomass energy and 8% is hydropower. These scenarios, which focus on international development equity and environmental protection, are based on accelerated energy efficiency. In 2050, energy demand is assumed to be approximately 600 EJ, and the CO_2 emissions in this scenario are approximately 5 GtC per year by 2050.

Table 1 Selected global energy scenarios that explore contributions of RE by 2050

	Total energy demand (EJ)	*Total renewable energy (EJ)*	*Total renewable energy (%)*	*Hydropower (%)*	*Wind power (%)*	*Bio-energy power (%)*	*Other renewable source (%)*	*CO_2 emissions 2050 (MtC)*
Renewable energy use 2000	425	56	13	2	0.03	11	App. 0	-
RIGES	512	237	46	3	-	33	10	4,191
IIASA AND WEC	479–1,040	96–308	22–40	-	-	-	-	5,110–14,670
IPCC	624–1,611	73–444	9–35	-	-	3–16	-	8,500–26,800
Shell	852–1,217	282–336	28–33	5–15	-	-	-	-

Source: Johansson et al. (2004)

The IPCC scenarios have a wider span regarding the contribution of RE in the future. In some scenarios, the share of RE is even expected to be lower than today. The scenarios, which are in all 40 and developed by six modelling teams, differ due to the differences in the driving forces for the scenarios, such as demographic change, social and economic development and rate and direction of technical change. This describes the sensitivity of the scenarios not only due to assumptions made but also due to methods use. These scenarios also have the lowest cumulative CO_2 emissions from 1990 until 2100. These scenarios are characterised by the introduction of clean and resource service and information economy with reduction in material intensity.

The scenarios by Shell show a considerable increase in the future share of RE. The shell scenario reflects a social shift in priority to a clean, secure and sustainable energy system and an intense competition between new and old technologies. The scenario describes a gradual shift to low carbon fuels and electricity supported by gas until 2025. The scenario illustrates a higher demand of energy to meet the energy needs of the citizens and also to meet consumers' preferences of mobility, flexibility, and convenience. At the same time, new energy technologies are introduced in developing as well as in developed countries making the RE an important source of energy.

3 Literature review/theoretical review

The analysis of the role of the financial sector – commercial banking, financial markets, insurance, etc. and economic performance has generated a vast literature during the past two decades.[6] The importance of the (private) financial sector particularly for the development of the energy sector has also been pointed out in several studies.

In one of the earliest analyses of energy sector financing in developing countries, Churchill and Saunders (1989) discuss a proper policy framework to encourage private sector financial involvement. Ten years later, Babbar and Schuster (1998), and Head (2000) still find substantial gaps in the financing of power projects, particularly RE projects. The financing obstacles for RETs are confirmed in the overview by Wohlgemuth and Painuly (1999), where efforts in different countries and regions are discussed and several policy recommendations derived. In like manner, Sonntag-O'Brien and Usher (2004), and Painuly and Wohlgemuth (2006) take a look at the experience to date with RET implementation in developing and transition countries, and again point to the (private sector) financing problems that RE projects encounter, as well as to some successful models that have been adopted.

MacLean and Siegel (2007) concentrate on the financing of small-scale RE projects and distinguish three financing areas: end-user finance, business finance and small-scale project finance. The need for well-informed (local) commercial financiers, often to act as financing partners for the government and/or international development organisations, is a recurrent theme in all three areas.

More recently, Brunnschweiler (2010a) examines the role of the financial sector development in RE in non-OECD countries. Panel data estimation on up to 119 non-OECD countries was used to confirm the influence of financial sector development on the use of RE resources. He pointed out that one of the obstacles of RE development is financing. The result shows that financial sector development does have a robust and significant positive effect on the amount of RE produced.

In Nigeria, Akinbami (2001) investigates the relevance of including RE resources into the nation's energy mix. He uses a large linear scale optimisation model, which is a representative of the highly nonlinear future of RE. The results of the model reveal that under a least cost constraint, only large hydro power technology is the prominent commercial RET in the electricity supply mix of the country. He further asserts that, despite the immense solar energy potentials available, solar electricity generation is attractive only under severe CO_2 emissions mitigation of the nation's energy supply system. He observed that, large hydro power technology takes the lion share of the entire commercial RE resources share for electricity generation under any CO_2 emissions constraint. The analysis reveals that some barriers exist to the development and penetration of RE resources electricity production in Nigeria's energy supply system. He therefore recommend that intensive efforts and realistic approach should be taken towards energy supply system in the country which must be adopted in order to adequately exploit RE resources and technologies for economic growth and development.

Sambo (1997, 2005) examines the importance of RE as an essential ingredient for socio-economic development and economic growth. He explained that the objective of the energy system is to provide energy services, and that energy services are the desired and useful products, processes or indeed services that result from the use of energy, such as for lighting, provision of air-conditioned indoor climate, refrigerated storage, transportation, appropriate temperatures for cooking, etc. He further highlights the role of RE for the rural development of Nigeria. The paper concludes that adoption of RETs especially for rural development will surely lead to reduced internal consumption of petroleum products. He recommends that strategies to promote the use of the sustainable energy systems and practices in Nigeria can only be realised with strengthened energy institutions.

In the study of Ilenikhena and Ezemonye (2010), the vital roles solar energy plays in Nigerian economy were X-rayed. He elucidates the necessity of solar radiation as one of the areas of focus among the RE resources in Nigeria. In spite of the efforts to create awareness on the effective use of solar energy, the technologies for solar energy applications are yet to become household commodities. His analysis shows that a greater percentage of all energy services are provided from electricity derived from burning of fossil fuel energy resources and hydro plants. Hence, he submits that the applications of solar energy to augment energy from fossil fuel energy resources should be strengthened through the use of cleaner fossil fuel technologies which will ensure availability of energy to meet the increasing demand in socio-economic activities and improved standard of livelihood.

However, most of these related studies in Nigeria are not empirically based, hence, the need for a study of this nature that empirically examines the impact of financial sector development on the use of RE resources in Nigeria.

4 Methodology and research methods

In this study, the model used to test the effect of financial sector development on RETs in Nigeria for the period 1980 to 2008 is represented in equation (1). Electricity generation per capital from RE technologies is used as a proxy for RETs.

$$\begin{aligned} RETS_t = {} & \beta_0 + \beta_1 CBAY_t + \beta_2 CCBY_t + \beta_3 M_2Y_t + \beta_4 FDIY_t + \beta_5 YPC_t + \beta_6 OP_t \\ & + \beta_7 CBAY_{t-1} + \beta_8 CBAY_{t-1} + \beta_9 CBAY_{t-1} + \beta_{10} CBAY_{t-1} + \beta_{11} CBAY_{t-1} \\ & + \beta_{12} CBAY_{t-1} + \beta_{13} CBAY_{t-1} + \varepsilon_t \end{aligned} \tag{1}$$

where $RETS_t$ is the RETs; $CBAY_t$ is the commercial banks asset share as a ratio of GDP; $CCBY_t$ is the credit provided by commercial bank to the private sector as a share of GDP; M_2Y_t is the financial depth: money supply as a share of GDP; $FDIYs_t$ is the ratio of net foreign direct investment inflows to GDP; YPC_t is the income per capita; OP_t is the price of crude oil; $CBAY_{t-1}$, $CCBY_{t-1}$, M_2Y_{t-1}, $FDIY_{t-1}$, YPC_{t-1}, OP_{t-1} are the first lag of all the explanatory variables, RETS t − 1 is the first lag of the dependent variable; and *å* is the stochastic error term.

According to Hansen (1982), it is ideal to add moment conditions by assuming that past values of explanatory variables, and even past values of the dependent variable, are uncorrelated with the error term. The inclusion of past values of both dependent and explanatory variables in the instrument set is due to their endogeneity. Then, the one step generalised method of moment (GMM) estimator of the coefficient vector β is given by:

$$\hat{\beta} = \left[X^{/} Z \left(\hat{\Omega}^{-1} \right) Z^{/} X \right]^{-1} \tag{2}$$

$$X^{/} Z \left(\hat{\Omega}^{-1} \right) Z^{/} X$$

where

$$Y_t = \left[y_{1T}, ..., y_{NT} \right]^1 \text{ and } X_t = \left[x_{1T}, ..., x_{NT} \right]^1 \tag{3}$$

Y_t and X_t represent vectors of the dependent and independent variables respectively.

This study employed the superior and more policy-applicable GMM methodology developed by Clarida et al. (2000) in estimating the equation, because the GMM in differences approach proposed by Hansen (1982) is plagued with the problem of weak instruments. Clarida-Gali-Gertler System estimator combines a levels equation, using lagged first differences as instruments. This permits exploiting several additional moment conditions that dramatically improve both consistency and efficiency for values of the coefficient of the lagged dependent variable.

4.1 Data issues

The dataset used for the empirical analysis consists of annual time series data for the period 1980 to 2008 on RETs, the commercial bank's asset share, the credit provided by commercial bank to the private sector, the financial depth, the net foreign direct investment inflows, the income per capita and the price of crude oil. All variables are expressed as a ratio of GDP except income per capita and the price of crude oil. Data were obtained from the world development indicator (WDI, 2009), international energy administration (IEA, 2009), central bank of Nigeria (CBN, 2009) statistical bulletin, and Nigeria deposit insurance corporation (NDIC, 2009) annual report and statement of accounts.

5 Results

5.1 Unit root tests

The time series properties of the data are examined to determine the order of integration of the variables included in the model. A series is said to be integrated of order d, denoted I(d), if the series becomes stationary or I(0) after being differenced d times. The Modified Ng-Perron and Dickey-Fuller-GLS tests are performed. Both the modified Ng-Perron and Dickey-Fuller-GLS statistics allow one to test formally the null hypothesis that a series is I(1) against the alternative that it is I(0). The results from both tests are consistent and show that all the variables are stationary at first difference (that is, they are integrated of order one). The results of the stationarity tests are shown in Tables 2 and 3.

Table 2 Ng-Perron modified unit root tests results

Variable	*MZa*	*MZt*	*MSB*	*MPT*
$_A$RETS	–1 8.3095**	–2.98284**	0.16291**	5.23398*
1%	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
5%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)
$_A$CBAY	–36.6269**	–4.27822**	0.11681**	2.49445**
1%	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
5%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)
$_A$CCBY	–42.4689**	–4.60430**	0.10842**	2.16534**
1%	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
5%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)
$_A$M$_2$Y	–18.3085**	–2.99108*	0.16337**	5.18460**
	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
1%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)
5%				
$_A$FDIY	–18.1961**	–2.85004**	0.15663**	5.98461**
1%	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
5%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)
$_A$YPC	–14.8762**	–2.48320*	0.16692**	7.49226**
1%	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
5%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)
$_A$OP	–65.4963**	–5.72259*	0.08737**	1.39135*
1%	(–13.8000)	(1.42000)	(0.14300)	(4.03000)
5%	(–11.3000)	(–2.81200)	(0.16800)	(5.48000)

Notes: $_A$ symbolises that the variables are in their first difference. The asymptotic critical values of Ng-Perron modified unit root tests are in their respective levels of significance. ** (*) denotes the rejection of the null hypothesis at 1% (5%) significance level.

Source: Computed by the author using E-views 7.1

Table 3 Dickey-Fuller-GLS unit root tests results

Variable	*T-statistics*	*1%*	*5%*	*Conclusion*
RETS	–3.5646*	–3.7700	–3.19000	I(1)
CBAY	–6.8197**	–3.7700	–3.19000	I(1)
CCBY	–6.1729**	–3.7700	–3.19000	I(1)
M_2Y	–9.1524*	–3.7700	–3.19000	I(1)
FDIY	–2.4689**	–3.7700	–3.19000	I(1)
YPC	–9.1097**	–3.7700	–3.19000	I(1)
OP	–6.6338**	–3.7700	–3.19000	I(1)

Notes: All the variables are stationary at first difference. The asymptotic critical values of Dickey-Fuller-GLS unit root tests are in their respective levels of significance. ** (*) denotes the rejection of the null hypothesis at 1% (5%) significance level.

Source: Computed by the author using E-views 7.1

5.2 Cointegration test

Time series variables which are not stationary may have some linear combination of them that is stationary. In such a case, the variables are said to be cointegrated. This implies that there is a long-run relationship among the variables. If the tests for stationarity reveal that most of the variables are not stationary, there is need to conduct cointegration test. In this study, following the Johansen and Juselius (1990) two likelihood ratio test statistics, the trace and maximal eigenvalue test statistics, were utilised to determine the number of cointegrating vectors. The results of the trace and maximal eigenvalue tests statistics are presented in Table 4.

Table 4 Johansen maximum likelihood cointegration test results

Trace test			*k=4*		*Maximum eigenvalues test*			*K = 4*	
H_O	H_A	*(ë trace)*	*Critical values*		H_O	H_A	*(ë max)*	*Critical values*	
			5%	*1%*				*5%*	*1%*
r ≤ 0	r > –0	144.49	95.75	104.65	r = 0	r = 1	50.44	40.08	51.80
r ≤ 0	r > –0	94.05	69.82	98.04	r = 0	r = 1	44.05	33.87	49.71
r ≤ 0	r > –0	49.99	47.86	85.3	r = 0	r = 1	27.06	27.58	28.96
r ≤ 0	r > –0	22.94	29.79	63.21	r = 0	r = 1	15.99	21.13	25.81
r ≤ 0	r > –0	6.95	15.49	36.98	r = 0	r = 1	6.94	14.26	19.78
r ≤ 0	r > –0	3.02	4.84	15.10	r = 0	r = 1	4.76	8.65	12.11
r~0	r > –0	0.02	2.44	7.85	r = 0	r = 1	0.02	3.84	7.28
r~0	r > –0	0.02	2.44	7.85	r = 0	r = 1	0.02	3.84	7.28

Notes: r represents number of cointegrating vectors and k represents the number of lags.
* (**) denotes rejection of the null hypothesis at the 5% (1%) level

Source: Computed by the author using E-views 7.1

The procedure followed to determine the number of cointegrating vectors began at the top of the table with the hypothesis that there are no cointegrating vectors, H_O. A rejection of the hypothesis would lead to testing the alternative hypothesis, which is H_A.

The testing procedure continues until the null hypothesis cannot be rejected any longer. Based on the test statistics, the hypothesis of no cointegration, H_O can be rejected. The results reveal that at least four cointegrating vectors exist among the variables of interest. Since the variables are cointegrated, there is, therefore, a long run relationship among the variables.

6 Discussion

The result of the GMM is reported in Table 5. The estimation weighting matrix is used to compute Standard errors and covariance matrix. Bartlett kernel, Newey-West fixed bandwidth is equal to 4.0000. The Instrument specification is of the order:

$$CBAY(-1)CCBY(-1)M_2Y(-1)FDIY(-1)YPC(-1)OP(-1)RETS(-1)$$

$$CBAY(-2)CCBY(-2)M_2Y(-2)FDIY(-2)YPC(-2)OP(-2)RETS(-2)$$

The long run effects are captured by adding a statistically significant number of lags. The variables of interest did not turn out to have any significant effects beyond two lags.

The main explanatory variables include three different indicators of financial sector development, and a vector of control variables. These measures of financial sector development are taken from Beck et al. (2000). They are not direct measures of banks' efficiency in credit allocation, but rather different proxies for financial intermediary development tested in the literature.

The first indicator of financial sector development, CBAY measures the commercial banks' asset share as a ratio of GDP. In open economies like Nigeria, the commercial financial sector handles a greater share of household savings. Assuming that the commercial financial sector is more efficient in allocating credits, CBAY should positively correlate with RET development.[7]

The second variable, CCBY captures the amount of credit provided by financial institutions to the private sector as a share of gross domestic product (GDP). It excludes credits issued by governments and development banks. An unrestricted financial sector can be expected to account for a larger share of lending to the private sector. In fact, this variable has been shown by Levine et al. (2000) to be a reliable measure of financial intermediary development, i.e., the ability of financial institutions to efficiently mobilise and allocate resources to profitable ventures. Earlier versions of the measure were used for example, in Levine and Zervos (1998). We expect CCBY to correlate positively with the level of development of the RE sector.

The third and final financial variable, M_2Y is a general measure of financial sector development commonly known as 'financial depth'. It is defined as liquid liabilities of the financial system – currency plus demand and interest-bearing liabilities of banks and other financial intermediaries or, more generally, M_2 divided by GDP. Financial depth is the broadest measure of financial intermediation, giving an indication of the overall size of the financial sector without distinguishing either between commercial and non-commercial banks and other financial intermediaries, or between the use of the liabilities. The assumption is that the relative size of the financial intermediary sector is positively correlated with the quantity and quality of the financial services provided, and we would therefore again expect a positive influence on the development of RETs.

Table 5 One-step system GMM results

Variable	*Coefficient*	*Std. Error*	*t-statistics*
C	3.6523	2.7835	6.4916
CBAY	4.6017**	9.5891	7.4805
CCBY	6.2768**	0.0482	12.8723
M_2Y	2.6986**	1.4301	1.3933
FDIY	0.05 18***	0.1061	1.1045
YPC	0.0326**	2.4578	2.6636
OP	–0.1246*	0.1611	0.7734
CBAY(–1)	2.3348***	0.3428	2.3371
CCBY(–1)	1.8751*	0.19076	1.2929
M_2Y(–1)	1.2179**	15.4370	3.4964
FDIY(–1)	–0.0725*	38.5895	2.7673
YPC(–1)	0.0004**	0.8758	1.8144
OP(–1)	–0.5094**	1.3605	0.3295
RETs(–1)	1.3260**	1.9364	1.4681
AR (2) test	Z = –1.59		
	[p-value = 0.13]		
Sargan test	Chi2 = 90.78		
	[p-value = 0.32]		
T-test: 4th lag	T = 1.32**		
	[p-value = 0.07]		

Notes: Two lags are included for both dependent and independent variables as instruments. T-statistics is reported on the fourth column. Variables entered with one period lag. ***, **, * indicates 1%, 5%, and 10% significance levels, respectively.

Source: Computed by the author using E-views 7.1

Several other control variables are included. Income per capita (YPC) controls for the possibility that Nigeria being a resource rich economy may simply have higher energy production. The ratio of net foreign direct investment inflows to GDP (FDIY) accounts for non-domestic investment, including investment by foreign institutions. It is expected that this measure will have a positive effect on RE sector development. The prices of the most common conventional fuels in Nigeria may also affect investment in alternative energy sources. We therefore control for the possible exogenous effects on RE development of the costs of non-RE resources production by including the market price of crude oil (OP).

It is of particular interest to observe the sign and statistical validity of the financial sector coefficients. The aim is to observe whether the development of the RE sector is – other things being equal – positively influenced by the financial intermediary sector, especially by the commercial banking system (proxied by the commercial bank asset share as a ratio of GDP (CBAY), the private credit allocation as ratio of GDP (CCBY), and broadly, the ratio of money supply to GDP (M_2Y). Controlling for variables like

YPC, FDIY and OP which affect RE or financial sector development allows us to draw conclusions on the impact of finance on RETs.

First of all, it is striking that all three financial sector development measures have the expected positive sign, and are moreover mostly significant at the 5% level, as far as the magnitude of the effects is concerned.

It is observed that a 1% increase in the commercial bank asset share as a ratio of GDP (CBAY), credit provided by commercial bank to private sector as a share of GDP (CCBY), and financial depth (M_2Y) would other things being equal, lead to increase of 4.60 17, 6.2768 and 2.6986 in the RE per capita produced, respectively. This suggests that the commercial bank asset share as a ratio of GDP, credit provided by commercial bank to private sector as a share of GDP, and financial depth have significant effects on the overall RE generation per capita in Nigeria.

On a closer look, the effects on the RE generation per capita are slightly smaller in magnitude for the net foreign direct investment as a share of GDP (FDIY) and income per capita (YPC). The coefficient values of 0.0518 and 0.0326 respectively suggest that a unit increase in net foreign direct investment and income per capita bring about 0.0518 and 0.0326 increase in RE generation per capita respectively.

However, it is revealing from the result that the coefficient of oil price (OP) is negative (–0.1246), and statistically insignificant at both 1% and 5% level. The non-significance of the coefficient of oil price implies that the generation of RE in Nigeria does not significantly depend on the price of crude oil. The intuition here is that a unit increase in the price of oil will bring about 0.1246 decreases in RE generation per capita. Meaning that the more the income generated by the Nigerian Government through increase in the price of crude oil, the less the interest in financing the alternative to non-RE (especially oil) in Nigeria.

The conclusion for this empirical exercise is that most of the commercial bank and macroeconomic variables in Nigeria are strong determinants of RETs, hence, stimulating the level of RE development. This inquiry however, is in consonance with the findings of Brunnschweiler (2010a) on finance for RE: an empirical analysis of developing and transition economies.

7 Conclusions

This paper examines the effects of financial intermediation on the development of the RE sector in Nigeria for the period 1980 to 2008. Energy production today relies on exhaustible and polluting conventional fossil fuels, and a larger share of alternative energy sources in primary energy production would not only have positive environmental effects, but would also bring greater energy security for future generations, as RETs exploit domestic RE resources.

Energy firms in Nigeria are largely dependent on external financing to realise new projects; in turn, external financing in Nigeria relies on the banking sector, as stock and bond markets, as well as venture capitalism, are not well enough established to provide large-scale funding. However, the underdevelopment of the banking sector, in addition to specific RE-sector problems such as high up-front and information costs and long lead times, hamper the emergence of RE entrepreneurs. The financing problems are combined with the greater issue of energy regulations and RET policies.

The empirical estimations, using RE electricity generation per capita as a proxy for RE sector development, show that financial sector development does indeed have a robust and significant positive effect on the amount of RE produced, which is independent of (or in addition to) energy policy. Of the three financial sector measures used, the commercial bank asset share and the private credit share proved the most robust, while financial depth is probably too broad a measure to adequately capture the more bank-focused development that is assumed to be important in developing and emerging economy like Nigeria.

8 Implications/limitations

Any policy recommendations must remain tentative at this point. Nevertheless, it seems safe to say that the financial sector does indeed have a measurable impact on the emergence of RE fabricators. A regulatory framework aimed at fostering the RE sector cannot neglect the financing aspects, and particularly the availability of private sector financial intermediation. Developing and strengthening the financial sector of course has greater macroeconomic benefits, as demonstrated by the vast finance and growth literature; however, it also has a non-negligible influence on the success of RE, especially the most recent non-hydro RETs.

The study suggests that a more highly developed financial sector will have a positive impact on the development of the RE sector. A well-functioning and unrestricted banking sector should be particularly relevant for credit allocation to RE companies in Nigeria where financial markets are relatively small and bond or equity financing is therefore difficult or impossible. Of course, a well-developed financial sector alone is no guarantee for the success of RETs: the availability of adequate financing mechanisms should be viewed in the wider context of an appropriate RE policy framework. Investment in RE and energy efficiency is important to reduce the negative economic, social and environmental impacts of energy production and consumption.

Pro-active and long-term policy-oriented RE programs aimed at decision-makers, in both government and the private sector should be initiated. The innovative energy policy program of the African Energy Policy Research Network (AFREPREN/FWD) provides a model example (Christensen and McCall, 1994). The policy programs should be designed to demonstrate the economic and environmental benefits of renewable technologies to Nigeria and other African countries. Long-term RE training programs designed to develop a critical mass of locally-trained manpower with the requisite technical, economic and socio-cultural skills are urgently needed. Many of the engineering and technical courses that are currently taught at universities and colleges in Nigeria and entire African countries provide little exposure to energy technologies. Modest changes in the curricula of existing institutions of learning in Nigeria (especially universities and polytechnics) could significantly increase the supply of skilled RE engineers, policy analysts and technicians. Both capacity and demand for local analytical expertise to provide comprehensive evaluations of available RE resources and options for utilising them are needed in Nigeria and all African countries.

Priority should be given to highlighting the real and tangible economic benefits (such as job creation and income generation) that RE programs can deliver to the region at both the micro and macro levels. For example, RETs are generally more labour intensive than

conventional and centralised energy projects and can help to address problems of employment of the urban and rural poor.

Government should make a statutory policy that mandates the banks to devote at least 10% of their annual lending to RE projects. This can be reinforced by giving tax concession to the banks that meet this minimum target of 10% so as to encourage compliance.

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Notes

1 RETs include both the more traditional hydropower technologies, as well as newer technologies that harness wind, solar, biomass and geothermal power.

2 Barbier et al. (2009) present a more extensive discussion of the short-to long-term environmental, social and economic benefits of RETs not only for developed, but also for developing countries

3 The theoretical contributions on this topic are equally scarce: one attempt to model the connections between finance and RE sector development is presented in Brunnschweiler and Earle (2006) and Brunnschweiler (2010b).

4 Details of these renewable energy sources are articulated in Sambo (2005)

5 Studies relevant to the availability of the solar energy resource in Nigeria are carried out by (Folayan, 1988; Sambo, 1997).

6 See for example, Brunnschweiler (2010) for an overview.

7 This variable has also been tested several times in the finance literature, e.g., in Levine et al. (2000).