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The socio economic drivers of rural electrification in Sub-Saharan Africa

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ABSTRACT

A significant proportion of the population in sub-Saharan Africa live in the rural areas, with the majority living on less than US$1 per day. Access to electricity is considered an essential element in the sustainable development of rural areas and an enabler for countries to achieve their Millennium Development Goals.

This paper contributes the first analytical study of the socio-economic factors which have a significant impact on rural electrification (RE) development in sub-Saharan Africa. The study employs cross-sectional data for 24 of the 47 countries in the sub-Saharan region and finds factors including the Human Development Index, wealth distribution, institutional development and urban population size of a country to have a significant impact on RE development. A detailed policy survey of four countries from the sample; two countries categorised as over-performing (Nigeria and Madagascar) and two as under-performing (Tanzania and Chad), highlights that collaboration with international partners, integration of national policies and strategies and the use of renewable energy sources enhances the development of rural electrification in sub-Saharan Africa.

Keywords: rural electrification; socio-economic factors; developing countries; Sub-Sahara Africa; sustainable development; MDGs; econometric modelling; policy survey.

The socio economic drivers of rural electrification in Sub-Saharan Africa*

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1. INTRODUCTION

Poverty is a major obstacle for sustainable development not only for developing countries but also the entire world. This is acknowledged by the United Nations member states who adopted the Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets - with a deadline of 2015 - that have become known as the Millennium Development Goals (MDGs)[1]. The partnership also includes a number of international organisations including the World Bank, International Monetary Fund, International Fund for Agricultural Development and World Health Organization. Although some countries are on track to meet the goals, other countries, particularly in Sub-Saharan Africa are not[2]. Tackling poverty has therefore become one of the main objectives of multilateral donors, such as the World Bank and other organisations, together with economic growth. One way of alleviating poverty is to promote access to modern energy, in particular to electricity[3].

In Sub-Saharan Africa, the rural population make up a significant proportion of the total population, where in most of the countries over 60 percent live in rural areas. The rural communities are key to increased

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economic production and social progress; however their contribution to the economy is muted due to inadequate policies, strategies and institutional frameworks for development. Electrification is seen as a crucial element in the sustainable development of the rural areas[4].

One major use of rural electrification (RE) is for lighting, which brings benefits of increased study time and improved study environment for school children, extended hours for small businesses, and greater security. Another common use is for television, which provides both entertainment and information such as health programmes. Thus electrification is thought to bring an improved quality of life. There is also a greater willingness of health and education workers to stay in communities that have electricity[5].

In the past RE projects have been assessed purely on financial terms and therefore deemed not viable. However in recent years there has been a shift in methodology for assessing the benefits of RE to include its impact on social welfare, which makes RE projects more acceptable.[5]

The majority of the research to date on electrification in developing countries considers either how (rural) electrification projects should be evaluated; how to assess the impact of electrification on poverty reduction and/or economic development; energy demand modelling to assess the relationship between electricity consumption and socio-economic factors such as economic growth, quality of life (education, health) or outlines the progress of electrification projects in developing countries.

A significant number of studies focus on developing countries in Asia, predominantly China and India, using energy modelling to examine the relationship between rural electrification and rural development.

Kanagawa[3] (2008) developed an energy economic model on rural areas for one State in India, using cross-sectional data. The research assessed the relationship between access to electricity and the advancement of the socio-economic conditions in the rural areas, with a focus on poverty reduction. Kanagawa concluded that the literacy rate above 6 years could be explained by household electrification rate, sex ratio and road density per 1000km sq, emphasising how educational improvements could be attained through access to electricity. Although the paper provides a good assessment of the relationships between electricity consumption and other socio-economic factors such as GDSP (gross domestic state products) and literacy rate, the focus is at the household level, and based specifically on the electricity consumption of lighting appliances.

Shiu[6] (2004) uses time series data from 1971 to 2000 to examine the causal relationship between electricity consumption and real GDP using the error-correction model for the whole of China. Shiu finds that for China there is a unidirectional Granger causality going from electricity consumption to real GDP but not the other way. The paper summaries the empirical findings of causality tests between energy/electricity and income for 11 Asian countries, which shows that for some countries unlike for China, real GDP drives energy consumption whereas in others there is a bi-directional relationship between energy consumption and real GDP. Shiu concludes that one of the reasons for the unidirectional relationship in China results from the lack of electricity access to a large number of the rural population due to insufficient capital investment in power sector infrastructure and high tariffs. The paper recommends that the government accelerate rural electrification.

Yang[7] (2003) analysed the impact of rural electrification on poverty reduction and rural economic development, using panel data on six provinces in China over a 20 year period, to provide recommendations to government and investors on how best to use their limited capital on rural electrification investment. The six provinces are categorised in pairs into well-developed, medium-developed and least-developed rural provinces. Yang concludes that rural electrification has the largest impact on economic growth in well-developed rural provinces and least impact in the least-developed provinces. With respect to poverty reduction, the largest impact was evident in the medium-developed provinces with limited impact in the well-developed and least-developed provinces. The paper provides guidance on how to formulate policy on rural electrification depending on what the primary objectives are; economic growth or poverty reduction.

The literature on rural electrification on countries in sub-Saharan Africa focuses on the assessment of existing policies or assessing field trials. Gaunt[8] (2005) examined the progress of electrification in South Africa and the impact that decisions taken to meet social objectives of poverty alleviation had on electrification by considering technology, financial, institutional and ethical aspects; and the implications for other developing countries based on the South African experience. Although electrification programmes are planned and evaluated on financial or socio-economic models, Gaunt finds that electrification is usually carried out as a social objective to alleviate poverty and for political reasons.

These multiple objectives for electrification cause confusion when formulating policy as reviews of electrification programmes based on socio-economic objectives have shown that the projects do not always meet all the objectives. The research found that financial constraints and a better understanding of customer requirements led to innovative research and development and the adoption of revised procedures and new technologies. This produced cost effective electrification programmes and prompted the extension of access to electricity in rural areas.

Ilskog & Kjellström[9] conducted field studies based on a methodology developed by Ilskog[10] for the evaluation of rural electrification projects with respect to sustainable development. The methodology considered the use of 39 indicators which covered five aspects of sustainability; technical, economical, social/ethical, environmental and institutional. The field studies were conducted for seven rural areas in Eastern and Southern Africa, to assess whether the contribution of rural electrification projects by the private sector or non-governmental organisations were more effective with regards to sustainable development than where rural electrification was the responsibility of government utilities. The authors concluded that government utilities performed better from a social/ethical perspective whereas the private organisations managed client relationships better. However, they point out that it is difficult to draw general conclusions from the studies due to the size of the sample used and the conditions under which the studies were conducted. Rural electrification is a developmental issue and therefore the proposed methodology which takes into account various aspects of sustainability is a better way of evaluating a project compared to a pure financial assessment. The methodology is also at the micro level and therefore there will be greater confidence in the accuracy of the data used for the assessment. However, the significant amount of information required for the evaluation process will present difficulty in most cases. It is also not clear how the conclusions drawn could be translated at the macro level to assist policy makers in decision making.

Bhattacharyya & Timilsina[11] (2009) conducted a survey to establish the most appropriate energy demand models for developing countries when modelling energy demand. The policy paper examines different types of energy demand modelling techniques; econometric, end-use approach, input-output, scenario and hybrid. They ascertain that although most of the mentioned models may be suitable for developed countries, they are not suitable for developing countries because of factors such as poor quality of information, and the fact that usually the past and future are not on the same trajectory due to structural changes and economic transition. Bhattacharyya & Timilsina consider end-use models to be more appropriate for developing countries and conclude that models for developing countries should include factors such as rural energy, informal economies, structural economic change, technological diversities, investment decisions, rural-urban divide and inequity. The focus of this paper is on energy supply rather than energy demand modelling, however, the work by Bhattacharyya & Timilsina provides useful insight into the difficulties associated with energy modelling of developing countries.

There are many facets of (rural) electrification; impact on economic growth, poverty reduction, improvement in the quality of life, and the complexity in project evaluation. The literature review highlights the factors which are important in developing a model; including economic factors such as GDP and capital investment but also social factors such as equity[11], social development[7,8,9,10], institutional development and technology[8,9,10]. However, there is no evidence from literature that an econometric study has been conducted on the sub-Saharan Africa region. The objective of this paper is to determine the socio-economic drivers which have a significant impact on rural electrification in sub-Saharan Africa. Bearing in mind the difficulties associated with energy modelling for developing countries[11], the paper also conducts a policy survey on four countries which are atypical from the norm to corroborate the econometric modelling and to provide additional information which shows good practice in the region.

The significance of conducting a study for the whole region is that the experiences obtained on countries over-performing the general trend would assist other countries in the region in improving rural electrification development.

2. METHODOLOGY

To determine the socio-economic factors which have an impact on the rate of rural electrification in Sub-Saharan Africa we develop an econometric model on 24 countries and go on to conduct a policy survey on four countries selected from the econometric analysis.

In line with the literature[7,8,9,10], the econometric model for rural electrification uses cross-sectional data and takes into account institutional, economic and social factors. Technological factors are excluded from the model, because technology is usually a time varying factor with no way of measuring technical progress across countries.

The general form of the econometric model used in the regression is:

$$RE_i = f(Y_i, HDI_i, GI_i, FDI_i, ID_i, NAI_i, UP_i) \qquad (1)$$

where *RE (rural electrification)* is the percentage of rural population who have access to electricity, and is the dependent variable. *Y (GDP/capita)* is an economic measure of a country's income per person and is used to measure the economic development. It is expected that the greater the development of a country the higher will be the level of rural electrification, and therefore one would expect a positive relationship with RE. *HDI (Human Development Index)* is used to rank countries by their level of "human development". The HDI combines normalized measures of life expectancy, literacy, educational attainment, and GDP per capita for countries worldwide and is also a measure of a country's development. One would therefore expect a positive relationship with RE. *GI (Gini Index)* is a measure of statistical dispersion most prominently used as a measure of inequality of income distribution or inequality of wealth distribution. A low Gini coefficient indicates more equal income or wealth distribution and is usually associated with developed countries. However, a high Gini coefficient indicates a more unequal income distribution and is usually associated with a developing country. RE is higher in developed than developing countries and therefore one would expect a negative relationship between GI and RE.

An increase in *FDI (Foreign Direct Investment)* would enable a country to have more funds available to implement Growth Poverty Reduction Strategy Programmes which usually involves development of rural areas. In addition, FDI may also have a social welfare element associated with it therefore a positive relationship with RE would be expected. The level of *ID (Institutional Development)* in a country is indicated by the policies, regulatory framework in place which would encourage investment in rural electrification by private investors, donor organisations, NGOs (non-governmental organisations) and so on. One would expect a positive relationship with RE. This variable is based on the Country Policy and Institutional Assessment (CPIA) ratings calculated by the World Bank's International Development Association (IDA). *NAI (Net Aid Inflows)* is usually associated with poverty reduction, and since rural electrification is seen as one way of alleviating poverty in the rural areas one would expect a positive relationship with RE. An increase in *UP (Urban Population)* could lead to an increase in revenue for the country. Thus one would expect a positive relationship with RE. *i* denotes a country in the sample.

The regression will start initially with equation (2)

$$ln(RE_i) = \beta_0 + \beta_1*ln(Y_i) + \beta_2*ln(HDI_i) + \beta_3*ln(GI_i) + \beta_4*ln(FDI_i) + \beta_5*ln(ID_i) + \beta_6*ln(NAI_i) + \beta_7*ln(UP_i) + u_i \qquad (2)$$

where based on the above descriptions, it is expected that

$\beta 1 > 0, \beta 2 > 0, \beta 3 < 0, \beta 4 > 0, \beta 5 > 0, \beta 6 > 0, \beta 7 > 0$ assuming $u_i \sim NID(0, \sigma^2)$

The common approach in the literature is to use natural logs because this enables the impact of the independent variables on RE to be observed in terms of percentage changes (i.e. coefficients are dimensionless). Various forms of equation (2) will be estimated to establish the preferred equation to be used to explain the factors which determine the rate of rural electrification in sub-Saharan Africa. The method of assessing the regression results will include (a) checking the statistical significance of the coefficients and their signs with respect to prior expectations, and (b) conducting a series of diagnostics tests (RAMSAY reset, heteroskedasticity and normality) to confirm the preferred equation.

The residuals from the preferred equation identified by the econometric study will be used to select countries, which are considered outliers from the general trend of rural electrification for further study in order to verify the appropriateness of the socio-economic factors determined by the econometric model. In theory, the residuals of a regression are considered random i.e. white noise. However in this case it is expected that the residuals would also contain information which are not explicitly explained by the explanatory variables in the equation. The assumption[12] here is that the residuals would provide information on how countries differ from the average rural electrification trend in sub-Saharan Africa i.e. country specific information. The residuals furthest from zero are used to determine the outliers i.e. countries significantly different from the norm. The countries with the largest positive residuals are considered over-performing and those with the largest negative residuals considered under-performing.

The policy survey will assess the external drivers which impact the development of rural electrification in each country by focusing on **PESTE** factors (**P**olitical/institutional, **E**conomic, **S**ocial (rural development and specifically rural electrification, **T**echnological (focusing on the electricity sector) and **E**nvironment). The results of the study are then analysed to verify the suitability of the socio-economic factors determined by the econometric model.

3. ECONOMETRIC MODEL

3.1 Data

There are 47 countries in sub-Saharan Africa. This study is based on 24 countries due to limited availability of the necessary data on the remaining countries. Sub-Saharan Africa is divided into four regions; West, East, Central and South. The countries to be investigated are grouped according to the regional location of each country as classified by the United Nations Statistics Division[13].

West Africa	***East Africa***	***Central Africa***	***Southern Africa***
Benin	*Ethiopia*	*Cameroon*	*Lesotho*
Burkina Faso	*Kenya*	*Chad*	*Namibia*
Ghana	*Madagascar*	*Congo, Rep*	*South Africa*
Guinea	*Malawi*	*Gabon*	
Mali	*Mozambique*		
Mauritania	*Rwanda*		
Nigeria	*Tanzania*		
Senegal	*Uganda*		
	Zambia		

The sample can be considered representative of sub-Saharan Africa because the sample size is approximately half the total number of countries, and it provides a good coverage of each region, varying levels of development and the range of incomes.

The data used in the model[14] is presented for economies as constituted in 2006, with any exceptions noted. However, the Country Policy and Institutional Assessment ratings are for 2008. The original data is presented in the appendix, Table A.1. The percentage of urban population used in the model is calculated from the total population and percentage of rural population. Since it is not possible to take natural logs of values less than or equal to zero, the numbers highlighted in Table A.1 were revised as follows; a rural electrification value of 0.1 percent was entered for Chad, and an FDI value of N/A entered for South Africa. The regression analysis was conducted in EViews Version 6[15].

3.2 Empirical Findings

The correlation matrix in Table 3.1 gives an indication of the relationship between the variables and shows that there is a strong correlation between the independent variable *Ln*(*Y)* and the independent variables *Ln*(*HDI), Ln(GI)* and *Ln(UP)*. The strongest correlation is with *Ln(HDI)*. This is not surprising since a third of HDI is derived from GDP per capita[16], and thus there is a high degree of collinearity between the two variables. In the case where there is multicollinearity the regression coefficients may be determined, that is they may be the Best Linear Unbiased Estimators (BLUE) - however they possess large standard errors which means that the coefficients cannot be estimated with great accuracy[17]. The large standard errors can lead to some of the coefficients being statistically insignificant. There is also correlation between *Ln(HDI)* and *Ln(UP)*, albeit not very strong.

There is significant correlation between the dependent variable *Ln(RE)* and the independent variables *Ln(Y), Ln(HDI)* and *Ln(UP)*. The strongest correlation between *Ln(RE)* and the independent variables is with *Ln(HDI)* followed by *Ln(UP)*.

Ideally one would prefer to have strong correlation between the dependent variable and the independent variables, and minimal correlation between the independent variables due to the issues of multicollinearity mentioned above.

Table 3.1: Correlation matrix of the variables

	LnRE	*LnY*	*LnHDI*	*LnGI*	*LnFDI*	*LnID*	*LnNAI*	*LnUP*
LnRE	1							
LnY	0.5211	1						
LnHDI	0.6958	0.7760	1					
LnGI	0.0987	0.6971	0.4934	1				
LnFDI	0.0976	0.4315	0.3554	0.3487	1			
LnID	0.2238	-0.0984	0.0723	-0.1437	-0.3978	1		
LnNAI	0.2220	0.0196	-0.0099	0.1563	-0.1004	0.2553	1	
LnUP	0.6609	0.6990	0.5647	0.3620	0.4916	-0.2461	0.2026	1

The results of the regression are presented in Table 3.2. The statistical significance of each variable and the adjusted R^2 were assessed following each regression, and the variable with the highest probability of having a coefficient equal to zero was eliminated in the subsequent regression. The preferred equation was determined from further estimations.

With the exception of *HDI* and *UP* (percentage of urban population) all the other coefficients were statistically insignificant at the 5 or 10 percent level for the initial equation. The coefficient for *Ln(Y)* had the highest probability of being zero and in addition its value was negative, which was not as predicted in section 2.1. This is probably due to the problem of multicollinearity highlighted earlier. One method of resolving this problem is to drop one of the variables, although this could lead to specification error[15]. *Ln(Y)* was therefore eliminated from the subsequent regression. Further estimations were then conducted, each time eliminating the variables that were statistically insignificant. Equation (2D) was selected as a preferred equation since all the coefficients were statistically significant at the 5 percent level and were of the expected sign.

$$ln(RE_i) = \beta_0 + \beta_1*ln(HDI_i) + \beta_2*ln(GI_i) + \beta_3*ln(ID_i) + \beta_4*ln(UP_i) + u_i \qquad (2D)$$

This equation also produced the highest adjusted R^2 value and passed all the diagnostic tests defined in section 2.1. The strong correlation between the independent variables *Ln(HDI)* and *Ln(UP),* and the dependent variable *Ln(RE)* shown in Table 3.1 is further confirmed by their presence in the final equation. The insignificance of *Ln(Y)* in the initial equation was attributed to its strong correlation with *Ln(HDI)*. However Table 3.1 also shows a strong correlation between *Ln(Y)* and *Ln(RE)*. Therefore another form of equation (2) was considered which in this case included *Ln(Y)* but excluded *Ln(HDI),* to establish if that equation would provide a better explanation for the rate of rural electrification. This alternative form will be referred to as the 'Y-model' and equation (2D) as the 'HDI-model'. The initial equation for the Y-model is defined in equation (3).

$$ln(RE_i) = \beta_0 + \beta_1*ln(Y_i) + \beta_2*ln(GI_i) + \beta_3*ln(FDI_i) + \beta_4*ln(ID_i) + \beta_5*ln(NAI_i) + \beta_6*ln(UP_i) + u_i \qquad (3)$$

The results of the Y-model presented in Table 3.2 show that for the initial equation, with the exception of Urban Population (UP), all the coefficients were statistically insignificant at the 5 percent level. Institutional development (ID) was statistically significant at the 10 percent level. Further estimations led to equation (3C) the preferred equation.

$$ln(RE_i) = \beta_0 + \beta_1*ln(Y_i) + \beta_2*ln(GI_i) + \beta_3*ln(ID_i) + \beta_4*ln(UP_i) + u_i \qquad (3C)$$

The coefficients of *Ln(GI)* and *Ln(Y)* were not statistically significant at the 5 or 10 percent level, and this can be explained by the high correlation between the two variables. As discussed earlier one would expect the standard errors to be large which would affect the t-statistic. Equation (3C) was therefore considered a suitable equation for the Y-model, albeit with the coefficients of *Ln(GI)* and *Ln(Y)* statistically significant at the 15 and 20 percent level respectively. Equation (3C) passed all the diagnostic tests and the sign of the coefficients were as predicted.

Table 3.2: Regression results

	HDI-model				Y-model		
	Equation 2A	**Equation 2B**	**Equation 2C**	**Equation 2D**	**Equation 3A**	**Equation 3B**	**Equation 3C**
C	3.8619	3.9468	2.9701	2.3360	-6.5969	-6.8348	-6.6483
	(0.6907)	(0.7308)	(0.5719)	(0.4541)	(-1.1728)	(-1.2788)	(-1.2932)
LNY	-0.0931				0.6722	0.6264	0.5838
	(-0.1840)				(1.2115)	(1.2718)	(1.3408)
LNHDI	4.8948	4.7581	4.4249	4.1751			
	(3.1565)	(3.6062)	(3.5855)	(3.4022)			
LNGI	-2.0257	-2.1728	-1.9750	-2.1305	-2.0665	-1.9427	-2.0605
	(-1.6077)	(-2.3023)	(-2.1978)	(-2.3796)	(-1.3131)	(-1.3783)	(-1.5377)
LNFDI	-0.1652	-0.1640	-0.1760		-0.1237	-0.1285	
	(-1.3701)	(-1.4053)	(-1.5392)		(-0.8261)	(-0.8947)	
LNID	2.1272	2.0835	2.5934	3.5757	3.8970	4.0607	4.6291
	(1.1437)	(1.1651)	(1.5761)	(2.3818)	(1.7592)	(2.0257)	(2.5823)
LNNAI	0.2743	0.2961			0.1029		
	(0.6711)	(0.7808)			(0.2033)		
LNUP	1.7334	1.6691	1.8227	1.6595	1.9645	2.0377	1.9002
	(2.7983)	(3.3653)	(4.0499)	(3.8220)	(2.5569)	(3.0905)	(3.0845)
Diagnostics							
Sample	23	23	23	24	23	23	24
Adj. R^2	0.6991	0.7172	0.7237	0.7419	0.5305	0.5569	0.6206
Akaike criterion	2.5733	2.4886	2.4390	2.4246	2.9957	2.9113	2.8099
Hetero (White)	$F(7,15) = 0.905$ (p=0.5281)	$F(6,16)= 1.068$ (p=0.4212)	$F(5,17)=1.024$ (p=0.4346)	$F(4,19)=1.160$ (p=0.3593)	$F(6,16)=0.557$ (p=0.7579)	$F(5,17)=0.649$ (p=0.6659)	$F(4,19)=1.19$ (p=0.3472)
RAMSAY reset	$F(2,13) = 1.256$ (p=0.3171)	$F(2,14)=1.255$ (p=0.3153)	$F(2,15)=1.532$ (p=0.2481)	$F(2,17)=2.315$ (p=0.1290)	$F(2,14)=0.801$ (p=0.4682)	$F(2,15)=0.728$ (p=0.4993)	$F(2,17)=0.936$ (p=0.4117)
Normality (Jarque Bera)	0.5564 (p=0.7572)	0.5938 (p=0.7431)	0.0494 (p=0.9756)	1.5463 (p=0.4616)	0.5503 (p=0.7595)	0.5233 (p=0.7698)	0.6019 (p=0.7401)

Comparison of equations (2D), HDI-model, and (3C), Y-model, indicate that in addition to either *HDI* or *Y,* for both equations the dominant socio-economic variables were *GI, ID* and *UP*. The models have confirmed the importance of economic factors as well as social factors such as equity, social development and institutional development in determining the rate of rural electrification as highlighted in the literature.

The only difference between the two models is whether *HDI* or *Y* should be selected. The points considered in assessing which model provided the best explanation of the development of rural electrification in sub-Saharan Africa were; statistical significance, average rate of rural electrification, adjusted R^2, Alkaike criterion, heteroskedasticity, functional form and non-nested tests, and these are discussed further.

The coefficients of the independent variables in the HDI-model are all statistically significant at the 5 percent level. However, that is not the case for the Y-model as mentioned and discussed earlier. The coefficient of the constant could be used as a measure of the average rate of rural electrification. In this case, the constant term is statistically insignificant at the 5 or 10 percent level for both equations (2D) and (3C). However making the assumption that some information could be obtained from this term then equation (2D) with a constant coefficient of 2.34 estimates an average rural electrification rate of 10.34 percent. Whereas, equation (3C) with a constant coefficient of -6.64 estimates an average rural electrification rate of 0.0013 percent. The average rural electrification rate in Sub-Saharan Africa as determined from Table A.1 is 10.13 percent, therefore the HDI-model appears to provide a more realistic estimate of the average rural electrification rate.

The adjusted R^2 value is 0.74 for the HDI-model and 0.62 for the Y-model, which indicates that the HDI-model better explains the rate of rural electrification compared to the Y-model. The Akaike Information Criterion (AIC) is a measure of the goodness of fit of an estimated statistical model. The AIC is not a test on the model in the sense of hypothesis testing, rather it is a tool for model selection. Given a data set, several competing models may be ranked according to their AIC, with the one having the lowest AIC being the best[18]. The Akaike criterion for the HDI-model is 2.42 and for the Y-model is 2.81, once again pointing to the HDI-model being the better model. However, both models passed the heteroskedasticity, function form and normality tests.

When you have two non-nested equations, (I) and (II), the non-nested test can be used to determine if additional information from equation (II) is not captured in equation (I) and vice versa. To conduct the test for equation (I), the fitted values of the dependent variable in equation (II) is included as a variable in equation (I) and the coefficients re-estimated. If the coefficient for the fitted values is statistically significant then there is additional information from equation (II) that is not captured in equation (I). The test is then repeated for equation (II) using the fitted values of the dependent variable from equation (I)[19].

A comparison of equation (2D) was made with equation (3C), by including the estimated fitted values of *Ln(RE)* from (3C) as follows;

$$ln(RE_i) = \beta_0 + \beta_1*ln(HDI_i) + \beta_2*ln(GI_i) + \beta_3*ln(ID_i) + \beta_4*ln(UP_i) + \psi*ln(\hat{}RE^Y{}_i) + u_i \quad (4)$$

The null hypothesis $\boldsymbol{\psi} = 0$ was tested using the conventional t-test for $\boldsymbol{\psi}$. Similarly, a comparison of equation (3C) was made with equation (2D), by including the estimated fitted values of *Ln(RE)* from (2D) as follows;

$$ln(RE_i) = \beta_0 + \beta_1*ln(Y_i) + \beta_2*ln(GI_i) + \beta_3*ln(ID_i) + \beta_4*ln(UP_i) + \varphi*ln(\hat{}RE^{HDI}{}_i) + u_i \quad (5)$$

and the null hypothesis $\boldsymbol{\varphi} = 0$ was tested.

The rejection of the null hypothesis in either case suggests that there is additional information from the alternative model not captured in the original model whereas acceptance suggests the opposite. The regression results for $\boldsymbol{\psi}$ (equ 4) and $\boldsymbol{\varphi}$ (equ 5) are presented in Table 3.3, with the t-statistics in parenthesis.

Table 3.3: Results of non-nested tests

$\boldsymbol{\psi}$	-0.1904 (-0.2537)
$\boldsymbol{\varphi}$	1.0493 (2.9251)

From the results, one cannot reject the null that $\boldsymbol{\psi} = 0$ indicating that with respect to the HDI-model no additional information can be obtained from the Y model. However, one can reject the null that $\boldsymbol{\varphi} = 0$ thus indicating that with respect to the Y-model **additional** information can be obtained from the HDI-model. This shows that of the two equations, (2D) provides a better explanation of the socio-economic factors that determine the rate of rural electrification in sub-Saharan Africa.

The series of tests suggest that the HDI-model is the preferred model which points to the fact that the socio-economic factors which significantly impact the rate of rural electrification are:

RE = f (HDI, GI, ID, UP)

RE = 3.4*Ln(HDI) – 2.38*Ln(GI) + 2.38*Ln(ID) + 3.8*Ln(UP)

However, it is believed that the Y-model has additional information which could enhance the selection of the countries for the detailed study.

4. ASSESSMENT OF NATIONAL POLICY

4.1 Selection of countries for further analysis

In the methodology described in Section 2.2, it is assumed that the residuals contain white noise as well as additional information that can be used to explain the rate of rural electrification in sub-Saharan Africa. Although the HDI model has been shown to be the preferred model for determining the rate of rural electrification, it is believed that taking into consideration the residuals from both the HDI and Y models would enhance the country specific information and reduce the impact of white noise. Figure 4.1 shows the residuals obtained from equations (2D) and (3C).

To verify the suitability of using both models, the Spearman rank correlation coefficient was calculated for the residuals from both models. The rankings of the residuals are shown in the Appendix, Table A.2. A Spearman rank correlation coefficient of 0.824 was calculated, which shows that there is a strong correlation between the ranking of the residuals for both the HDI and the Y models and confirms that using the residuals from both models should enable more accurate country specific information to be determined.

Figure 4.1: Residuals from Equation 2D (HDI-model) and 3C (Y-model)

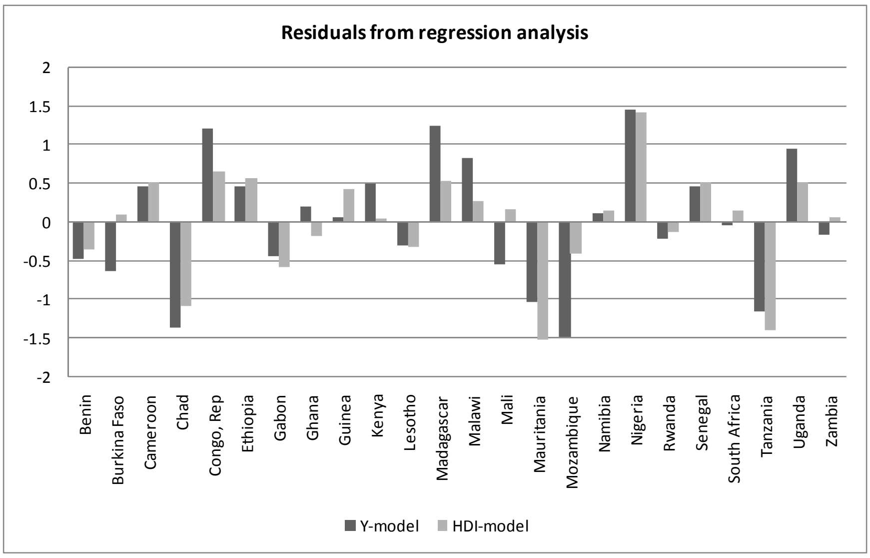

Table 4.1 presents the initial countries selected for further study based on the rankings (Table A.2) for both models. Ethiopia was not selected because although it ranks 3rd the HDI model, it ranks 9th in the Y-model. However, Madagascar ranks 4th and 2nd in the HDI and Y-models respectively. Table 4.1 also

includes information on country location and population. The additional factors of population and location were also taken into consideration to ensure that the countries selected for the detailed survey were also representative of the sub-Saharan African region.

Table 4.1: Initial country selection for further analysis

Countries		**Location**	**Population (million)**
Over-performing	Nigeria	West	144.7
	Congo, Rep	Central	3.7
	Madagascar	East	19.2
Under-performing	Chad	Central	10.5
	Tanzania	East	39.5
	Mauritania	West	3

The average country population in sub-Saharan Africa excluding Nigeria is approximately 15 million. The average based on the countries presented in Table A.1 is 18 million, excluding Nigeria. Taking average population and location into account, the selected countries for detailed study were Nigeria, Madagascar, Chad and Tanzania.

4.2 Review of Country Information

The purpose of the detailed study was to determine if additional information could be obtained from the error term to augment the results of the econometric study. The detailed study was based on information up to 2008, and assessed the external drivers which impacted on rural electrification in each country in relation to **PESTE** factors.

(a) Nigeria

Political/Institutional: Nigeria held elections in April 2007, which was the first democratic political transition since independence in 1960. There were widespread allegations of fraud and intimidation; nevertheless the new president assumed office peacefully and with a commitment to continue with the economic reforms of the previous administration. The guiding framework for economic reforms is the National Economic Empowerment and Development Strategy (NEEDS)[20] which focuses on driving economic growth, reducing poverty and achieving the Millennium Development Goals (MDGs)[21]. NEEDS provides a framework for a nationally coordinated programme of action by the federal, state and local governments. For the programme to be successful, it requires effective co-ordination between all the tiers of government with clearly delineated roles and responsibilities for each level of government. An Independent Monitoring Committee, co-ordinated by the business community is seen as essential to the whole process.

The sectors that were identified as key to poverty reduction were health, education, electricity, roads and water. These sectors received 60 percent of the total capital budget in 2004[20].

Economic: The leading sectors[21] are oil (37.3 percent) and agriculture (31.7 percent) with other services including telecommunications (12 percent) and general commerce (14.9 percent). Agriculture is considered the dominant economic activity in terms of employment and linkages with the rest of the economy. The agriculture sector comprises predominantly small farmers with low and declining productivity[20].

Nigeria's external debt was greatly reduced in 2007. It was expected that the huge drop in external debt and debt-servicing would make more resources available for investment in infrastructure, poverty alleviation and security improvement.

One of the main constraints to economic growth is the extremely high level of corruption in Nigeria – NEEDS quotes "*by 1999 corruption was practically institutionalised*". It pervaded both private and public institutions and plagued all levels of government and discouraged foreign investment in the country. The government established the Independent Corrupt Practices Commission (ICPC) in 2000 and the Economic and Financial Crimes Commission (EFCC) in 2003 to fight corruption.

Social: Nigeria has the largest population in Africa. 70 percent[22] of the population live in the rural areas[20]. The Energy Commission of Nigeria (ECN) states that the rural electrification rate in 2006 was 15 percent[23] which is significantly lower than the World Bank data of 35 percent in Table A.1.

As part of implementing NEEDS, there is emphasis on state and local government developing their own programmes, benchmarks and targets and implementing guides to reduce inefficient resource allocation and to ensure an integrated approach to rural development which will be effective in poverty reduction.

The 2007 Progress Report[24] shows the improvement in the agriculture, education and health sectors since the implementation of NEEDS. The National Rural Electrification Program started in 1981 with the aim of connecting all local government headquarters and a number of important towns to the national grid. The Program was constrained by several factors including NEPA's operational difficulties and rural electrification being driven by political rather than social and economic reasons. The 2005 Electricity Act also led to the creation of the Rural Electrification Agency (REA) and the Rural Electrification Fund with a more expansive agenda of providing reliable and affordable electricity supply to all rural dwellers. The REA inherited 1500 uncompleted grid extension projects, which are at various stages of completion[25]. However allegations of fraud by the REA management could hinder the progress of RE projects.

Technological: The main sources of existing electricity generation are natural gas (70 percent) and hydro (30 percent) (percentages are with respect to energy produced). Nigeria has an abundance of renewable energy sources; biomass, wind, solar and small hydro plants (SHP). Increased penetration of renewables into the energy mix is seen by the ECN as the solution to improving the quality of life and untapped economic potential of the rural population[26]. The Sokoto Energy Research Centre in Nigeria has implemented several pilot solar electrification systems sponsored by ECN in collaboration with state governments and private organisations. Various types of rural renewable projects; public-private partnership of SHPs, collaboration with international governments and institutions for SHPs, pilot wind power project; are documented[25].

Nigeria's power system was deemed unreliable and incapable of meeting demand, to the point of holding back economic progress. One of the goals under NEEDS was to deregulate and liberalize the electricity industry to encourage private sector participation, attract investment and encourage the use of alternative energy sources[20]. The 2005 Electricity Power Sector Act abolished monopoly power of National Electricity Power Authority (NEPA), the state owned company, which led to the unbundling of NEPA. Despite the recent changes, there remain difficulties in the power sector; supply/demand imbalance, inefficiency in transmission and distribution, slow pace of privatization[23].

Environment: More than 60 percent of the rural population depend on wood fuel for domestic and commercial uses. This leads to deforestation, desertification, air pollution from cooking which poses health hazards, which adversely impacts the rural population in particular[25]. Since 2004, environmental protection and conservation have been scaled-up. In addition a number of institutional and policy reforms have been established[22].

(b) Madagascar

Political/Institutional: The incumbent president was re-elected in December 2006 with firm parliamentary support for implementing the 2007 – 2012 Madagascar Action Plan (MAP)[27], which was adopted in November 2006. However, the discredited opposition won control of the capital, Antananarivo at the local elections in December 2007. A national anti-corruption council was set up in 2003 to fight corruption. This and other efforts such as the set up of the Independent Bureau against Corruption improved its CPI[28] from 1.7 in 2002 to 2.8 in 2005. The government is aiming for a score of 5.2 by 2012[21].

The driving force behind the MAP was the government's commitment to achieving the Millennium Development Goals (MDGs). The strategies and measurable targets defined in the MAP were SMART, with specific agencies made responsible for each target. Implementation of the MAP involved the development of a monitoring system[29]. 2007, the first year of the implementation of the MAP, involved the development of different management, implementation and monitoring tools including the National Integrating Monitoring and Evaluation System (NIMES). All stakeholders (government, technical and financial partners, private sector) were involved in the development of priority indicators selected to reflect the level of achievement of objectives under the MAP. Madagascar was selected as one of the pilot countries for the UN Public-Private Alliance for Rural Development (UNPPA), which promotes an integrated approach to rural development for poverty eradication and sustainable development. It considers that the provision of roads, transport, water and irrigation, power and telecommunications are important elements of rural infrastructure essential for rural transformation[30].

JIRAMA is the national energy company for water and electricity, and is solely owned by the government. Since liberalization in 1999, it has retained monopoly in transmission and distribution. However it is not the sole source of electricity production as there is now private participation in power generation. The Rural Electrification Development Agency (Agence pour le Développement de l'Electrification Rurale (ADER)) was created in 2002, and is responsible for implementing government policy on rural electrification. There are several partnerships with international agencies for rural development[31, 32].

Political crisis since January 2009 has had a negative impact on developmental efforts[30].

Economic: The dominant economic activity is in the tertiary sector (i.e. service industry – banking, insurance, telecommunications and tourism) which contributed roughly 50 percent of GDP in 2006. The agricultural (primary) sector is the next key sector, which contributed 27 percent of GDP in 2006[21]. There is significant economic activity in the rural areas comprising agriculture, ecotourism and handicrafts. The main agricultural activities include litchi, rice, jatropha, vanilla, coffee and spices[33].

Social: Over 70 percent of the country's population live in rural areas (a range of 70 – 80 percent is noted in various literature), with most living on less than $1 per day. Rural development is one of the key objectives of the MAP. The Malagasy government is involved with a number of international agencies; IFAD[34], World Bank, ILO[35], UNDP; to promote growth in the agricultural sector and agro-based industry[30].

The Rural Electrification Development Agency (ADER) website[36] lists the existing and planned rural electrification projects. Majority of existing rural electrification is decentralised. There is also evidence of several planned public private electrification projects, both grid extensions and off-grid systems.

Technological: The source of electricity production mainly comprises hydropower (64 percent) and thermal (36 percent) as at 2005 (percentages are with respect to energy produced). Fluctuations in oil prices resulted in high production costs for thermal plant and a financial crisis for JIRAMA. This resulted in power shortages with severe consequences to business activity[37]. The 2009 PRSP indicates that the energy demand is still not being met due to technical issues (dilapidated equipment) and the continued financial issues of the company. As a result of the problems faced by JIRAMA, the targets set for rural electrification in the MAP have not been met. As at 2006 the restructuring of JIRAMA was still ongoing[27]. However, a number of independent power producers and private investors have emerged which have enabled an increase in installed power between 2006 to 2007[29].

Environment: Globally, Madagascar is one of the richest nations in terms of biodiversity; however severe poverty could have a negative impact on the environment where poor management of agricultural resources could lead to increased poverty and greater need for agricultural expansion. One of the key goals of the MAP is to protect the environment by developing industries around it such as eco-tourism and sustainable farming[30].

(c) Tanzania

Political/Institutional: Tanzania is politically stable but there are growing concerns over the effectiveness of the government to fight corruption. Civil society with the help of the media has pushed for accountability. Parliament has backed these efforts where opposition parties have challenged alleged corruption by government officials. The major unresolved issue is the political impasse between the government and the major opposition party in the Zanzibar islands. However, steps are being taken to resolve the problem ahead of the next presidential elections in 2010[38].

A National Energy Policy was adopted in 2003 with an objective to aid the development process of the country by establishing an efficient energy sector in an environmentally sound manner. The Tanzania Electric Supply Company Limited (TANESCO) is a state owned monopoly company responsible for generation, transmission and distribution. In 2000, the power generation sector was deregulated to allow the participation of Independent Power Producers (IPPs) and by 2009 account for 290MW[39] of generation. One of the objectives of the National Energy Policy was to encourage private sector participation in the energy sector which was going through parliament during 2009.

The Rural Energy Agency (REA) is an autonomous body under the Ministry of Energy and Minerals, and became operational in 2007. Its main role is to promote and facilitate improved access to modern energy services in rural areas in mainland Tanzania. The Rural Energy Fund (REF), established at the same time, is responsible for providing grants to qualified project developers. REF receives funds from government, international financial organisations, multilateral and bilateral agencies and other development partners[40].

Economic: Agriculture is a key economic activity which employs 82 percent of the workforce and accounts for 60 percent of all exports. Agriculture contributes 26.5 percent[21] to GDP and is a crucial source of income particularly for the rural population. The contribution of agriculture to GDP varies in literature (ranging from 27 to 45 percent) however it remains the dominant economic activity. Diversification into non-farm activities in the rural areas has not been effective because they have been on a small scale. Mining is one of the fastest growing economic sectors in Tanzania. Artisanal and small-scale mining has been an alternative source of income for rural communities; however there are potential problems with large-scale operators about land rights[41].

Social: Over 75 percent of the country's population live in rural areas, with the majority living below the poverty line. Poverty in the rural areas is highest amongst households that depend on agriculture. 2 percent of the rural population have access to electricity. The target is for 15 percent of the rural population to have access by 2015. The strategy is to use low-cost electrification for remote rural areas, and apply renewable energies (solar, wind, biomass and mini-hydro).

The REA through the REF has funded ten projects by 2009 since its inception – all of which are grid extensions to un-electrified commercial centers with TANESCO, the state-owned utility, as the project developer. REA is currently collaborating with TANESCO on future projects which comprise both grid extensions and isolated systems based on renewable sources for rural electrification[42].

TaTEDO[43] rural development initiatives include among others the productive uses of sustainable energy for income generation and social services improvement – focusing on off-grid electrification. One of these initiatives is the use of Jatropha oil to power Energy Services Platforms[44, 45] which is supported at ministerial level in government. This has the combined benefit of the provision of modern energy services for the rural community plus income generation from growing Jatropha to alleviate poverty. The US government through USAID has given Tanzania \$5.4 million for the development of Jatropha farming in rural areas[46]. TaTEDO collaborates with other international NGOs and companies through the Enabling Access to Sustainable Energy (EASE) network. A 2006 article in the EASE newsletter suggests that there is no consistency between the national energy policy (which aims to ensure availability of reliable and affordable energy supplies for all in a sustainable manner) and plans relating to national economic planning. Thus the implementation of the energy policy would require synchronisation with the policies, plans and strategies of other sectors if they are also to achieve their development goals[47].

Technological: The electricity supply comprises both grid and off-grid (isolated) systems. Hydro accounts for roughly two – thirds of the electricity supply and thermal (natural gas/diesel generation) constitutes the rest. Drought conditions led to a severe power crisis in recent years resulting in power shortages. This was further compounded by high oil prices.

Tanzania has significant energy resources which include hydro, biomass, natural gas, coal, wind and solar. However with the exception of hydro and natural gas, little of the other energy resources have been commercially exploited.

Environment: Majority of the energy consumed is traditional biomass, predominantly wood fuel, which constitutes about 90 percent of the total primary energy consumption. More than 80 percent of the total primary energy, which is mainly in the form of biomass, is consumed in rural areas[47]. The negative impacts of this on rural communities are several; the use of wood fuel for cooking creates indoor pollution which leads to poor health particularly for women and children, environmental issues of deforestation and climate change, reduced productivity and therefore income from inefficient use of energy. One of the objectives of the Energy Policy is to address the environmental problem.

(d) Chad

Political/Institutional: Chad is a landlocked country, sharing its borders with six countries and also considered one of the poorest in Africa. It achieved independence in 1960. The 1996 Constitution was amended in 2005 to enable the President of the Republic to be elected several times[48].

Significant oil reserves were discovered in the Doba region. Oil production which started in 2003 was partly financed by the World Bank. 80 percent of the project royalties and dividends were to be used to reduce poverty in the priority areas such as health, social services, education, rural development (agriculture and livestock), infrastructure, environment and water resources. This has not materialised and has created growing resentment towards the government which is seen as corrupt and inept in its management of the oil revenue, leading to political tensions with attempts to overthrow the government[49].

Chad Water and Electricity Company (STEE), a state owned company, holds a monopoly on the distribution of water and electricity, with prices fixed by ministerial order according to a price structure[48]. There are plans to privatise the company. A National Rural Development Strategy was presented to the international community in 1999 to help increase productivity, crop diversification and ensure food security in the rural areas. Although the pace of implementation is slow, there has been some improvement in production and the dissemination of new techniques. However, a number of issues still remain such as insufficient resources and lack of proactive policies to improve the performance of the rural sector and particularly rural electrification[50, 51].

The objectives of the 2003 PRSP[50] have not been fully integrated into the daily management of national institutions and consequently have not formed part of institutional and sectoral priorities and budgets. For any real change to be effected, the national policies have to be incorporated into specific institutional and sectoral programs with realistic performance indicators. Despite being oil-rich, Chad is a poor country with limited resources and still requires extensive international assistance to finance its development and help in implementing the sectoral strategies[51].

Economic: Oil represented roughly 47 percent of GDP in 2006. The next major sector was the primary sector; agriculture (e.g. cereal production, cotton, gum arabic) and livestock breeding; which contributed approximately 18.7 percent of GDP in 2006[21]. Before 2003, the rural sector was the driver of the Chadian economy, accounting for 40 percent of GDP and employing 80 percent of the active population, majority of whom live in the rural areas. Major exports apart from oil are cotton, live cattle and gum Arabic[48].

Cotton is produced by small producers and is the main source of income in rural areas. However the fall in international cotton prices, difficulties at Cottonchad (the state-owned cotton company), the landlocked position of the country and the poor road infrastructure makes Chadian cotton uncompetitive and adversely impacts the income of the rural population[48].

Social: Chad is divided into three distinctive climatic zones; the Saharan desert, Sahelian and Sudanese or tropical, each with different agricultural capabilities[48]. Traditional methods are still used in farming and livestock breeding (extensive pasturing and herding are the norm). As a result both activities are heavily dependent on climatic conditions as well as damaging to the environment[50].

There is uneven distribution of basic social services (health, education, water electricity) between the capital city and other towns, and between urban and rural areas. This results from institutional and human shortcomings, and poor political choices. Most health and educational facilities are found in the urban areas with majority of rural areas having no schools or health facilities. Other services; telecoms, water, electricity, courts, prisons are only in urban areas[50]. Although some progress has been made in the education and health sectors, both sectors continue to be plagued with problems such as lack of suitable personal and resources, limited training, inadequate materials[51].

Technological (Electricity Sector): Only 2 percent of the total population have access to electricity – majority of whom live in the capital N'Djamena. 100 percent of power generation is from fossil fuel. Despite being an oil exporter, Chad imports petroleum for power generation. Consequently its electricity prices are one of the highest in the world[38]. A number of crisis measures were proposed to reduce the cost of electricity and expand access, some of which have been implemented; a refinery at Farcha to supply fuel for power stations, a power station at Farcha, however a national plan is required to resolve the energy problem. A national energy strategy and rural electrification plan are at the planning stage[51].

No information was found on alternative energy sources in Chad although PRSP 2007 does indicate that solar and wind energy need to be investigated for rural electrification.

Environment: Traditional biomass (wood fuel and charcoal) provide 90 percent of the energy consumed in Chad and is a major contributor to deforestation. Traditional methods in farming and livestock breeding also contribute to deforestation and desertification. Environmental policies are being put in place to protect the environment as this is seen as essential to the continuation of core economic activities and of reducing poverty[51].

4.3 Analysis

(a) Nigeria

Nigeria is politically stable as at 2009. The economic reforms started in 2004 placing rural development at the top of the political agenda, recognising that development of the rural areas would reduce poverty, ensure food security for the country and protect the agricultural sector which is the second source of the nation's wealth. The reduction in Nigeria's external debt in 2007 should release more resources for investment in rural development. There is integration of policies at the national, state and local levels to ensure effective implementation of programs. In addition there is collaboration with international governments and institutions with regards to rural electrification.

However the unreliability of grid connected supplies and the level of corruption in the country, particularly with regards to the REA fraud allegations currently being investigated may hinder the progress of RE. In addition, the inconsistencies in the data for the rural population and rate of rural electrification create some doubt in the performance of Nigeria with regards to rural electrification.

(b) Madagascar

There has been significant progress in rural electrification because government policies for rural development are at the national level. In addition, Madagascar benefits from extensive public private partnerships with international agencies and private investors for rural development, including rural electrification. The increase in rural electrification is one of the objectives of the MAP, and is not seen only as a social function to eradicate poverty (i.e. improved access for individuals, education, health, water and telecoms) but also for economic development due to extensive agriculture opportunities. Rural electrification is considered an important indicator in the monitoring process.

There is the emphasis to further develop rural electrification to drive growth in the whole economy. One of the constraints is the poor quality of supply by the national carrier JIRAMA. However the indication is that majority of the planned rural electrification is off-grid. Therefore it is expected that the increase in rural electrification would continue provided there is political stability in the country.

(c) Tanzania

Government policies indicate the awareness of the low level of electrification in the country, particularly rural electrification and the need to develop plans and strategies for rural development to alleviate poverty and improve the quality of life. Improving energy access is considered an important aspect of rural development, and specific targets for rural electrification are stated in PRSP 2006. The Rural Energy Agency only became operational in 2007 and has implemented a number of projects with several in the planning stages. Majority of the existing rural projects are owned or supported by TANESCO and tend to be grid extensions. Unlike Madgascar, there is limited international private investor involvement. This may improve with the privatisation of TANESCO.

Similar to Madagascar, there are significant economic opportunities in the rural areas of Tanzania. However public – private partnerships with international agencies and private investors are limited although this is starting to improve (e.g. USAID for Jatropha). Therefore with better national co-ordination in the policies of different sectors and improved international partnerships there could be significant improvement in the rate of rural electrification in the years to come.

(d) Chad

There is virtually no rural electrification in the country. Despite being oil-rich, Chad is a very poor country where the majority of the population, in particular the rural population, have limited access to basic services; education, health, water and electricity. The government is seen as corrupt and having mismanaged oil revenue to be used for poverty reduction. There appears to be no integration of policies at the national or sectoral level and therefore it is doubtful how effective developmental programs for the whole country, and particularly the rural population, will be in the near future. Political tensions in the country also hinder progress since resources are then diverted to providing security for the incumbent. International involvement is limited, particularly private investors, as a result of the poor political and institutional environment.

The national energy and rural electrification plans are now being developed. Until there is significant improvement in the development and implementation of institutional and sectoral programs, it is unlikely that rural development will become a priority.

4.4 Findings of policy assessment

(a) Over-performing countries

Despite the concern with regards to data from Nigeria, there are some common factors which differentiate over-performing (OP) countries from the under-performing (UP) countries. The countries are politically stable and an appreciable proportion of the urban population have access to electricity which enables the government to consider extending electrification to rural areas. Rural development and electrification is at the top of the political agenda because it is perceived as both an economic (increasing the wealth of the nation) and social (reducing poverty and meeting MDGs) function. Rural electrification is not seen as the sole responsibility of government rather there is the understanding of the importance of international public private partnerships on RE projects. This is particularly evident in Madagascar. The Institutions are further developed; in particular the Rural Electrification Agencies have been in operation for much longer. There is also greater collaboration between national and sector departments because of the awareness that lack of energy access impacts other basic services; education, health and water resources.

Rural electrification in OP countries involves both grid connected and off-grid systems. The off-grid systems comprise mini-grids and isolated systems usually based on renewable energy sources, with the countries showing greater application and experience of alternative energy sources. Evaluating performance of the RE programs is key to ensuring continued development. To that end, the OP countries have Independent Monitoring bodies to assess the progress of Program objectives.

(b) Under-performing countries

Tanzania has some of the characteristics of the OP countries; it is in the initial stages of using off-grid renewable energy sources, specifically bio-fuel technology, but its REA is in its infancy compared to the OP countries and there is less collaboration both nationally and internationally. In addition the current level of electrification in the country is low. However as these factors improve it is expected that the rate of electrification would significantly improve.

Chad on the other hand has a lot of work to do in all areas assessed; institutional, economic, social and technology. It is unlikely that the rate of rural electrification would change appreciably in the next few years.

(c) All countries

There are some factors which are common across the countries; there is significant use of traditional biomass in all the countries with its negative impact on the environment. Nigeria and Madagascar are further ahead in dealing with the problem however a mental shift is required by majority of the population in all countries. The perceived greater corruption in sub-Saharan Africa compared to developed countries. Most of the selected countries appear to recognise the detrimental effect of corruption and are taking steps to tackle the problem.

5. CONCLUSIONS

The rural population exceeds 60 percent in most countries in sub-Saharan Africa, majority of who live on less than $1 per day. Most of the countries are committed to achieving the Millennium Development Goals by 2015 which includes halving the population living below $1 per day and improving health and education. Access to electricity is seen as an essential element in the development of the rural areas to eradicate extreme poverty and improve the quality of life. The objective of the paper was to assess the socio-economic factors which have a significant impact on rural electrification in sub-Saharan Africa.

The literature review indicated that a combination of institutional, economic, social and technological factors needed to be considered when assessing rural electrification. An econometric model, using cross-sectional data for 24 countries, was developed based on variables which took into account the above factors with the exception of technology. The results of the econometric study indicate that the factors which have a significant impact on rural electrification are; the Human Development Index, wealth distribution, the level of institutional development and the size of the urban population. The supplementary detailed policy survey conducted on four countries from the sample; Nigeria, Madagascar, Tanzania and Chad, examined the external drivers (political/institutional, economic, social, technological and environment) which impacted rural electrification.

The policy survey indicated that a number of issues are important to the development of rural electrification; the level of institutional development including the collaboration of policies and strategies of different sectors, the involvement of the international community including public private partnerships, the focus on poverty reduction by focusing on both social (provision of basic services health and education) and economic aspects, the concern of government to improve wealth distribution, and the emphasis on sustainable development (i.e. the use of alternative energy sources) the benefits of which are two-fold; reducing environment degradation as well as extending electricity access to areas beyond the grid and possibly at lower cost.

The policy survey supports the findings of the econometric study. It also suggests that the use of renewable energy sources and international/national collaboration plays an important role in increasing the rate of rural electrification.

The research has shown that rural electrification has both economic and social benefits. It is therefore recommended that other countries in sub-Saharan Africa adopt policies which take the findings in this paper into consideration.

Recommendations for further research

The literature search indicates this is the first attempt at this type of study for sub-Saharan Africa. Therefore further research could consider whether the use panel data would be beneficial. The detailed study indicates that the provision of electricity by the incumbent electricity utility is inadequate. Most of the countries are considering a form of structural reform of the industry to provide reliable supplies for both the urban and rural population. Therefore further research could assess the impact of structural reforms on rural electrification.

APPENDIX

Table A.1: Country Data

Country	Population	Rural population	GDP per capita	Access to electricity	Gini Index	HDI [10]	FDI	CPIA [6]	Net Aid per capita	FDI per capita [7]
	(million)	(% of total pop.)	(2000 $)	(% of rural pop.)			$ million		$	$
Benin	8.8	60	323	6	36	0.459	53	3.6	43	6.0
Burkina Faso	14.4	81	258	1	40	0.372	8	3.7	61	0.6
Cameroon	18.2	45	686	16	45	0.514	21	3.2	93	1.2
Chad	10.5	74	266	**0** [8]	52.3 [1]	0.389	709.5 [4]	2.6	27	67.6
Congo, Rep	3.7	39	1145	16	56.2 [1]	0.619	724	2.7	69	195.7
Ethiopia	77.2	84	161	2	30 [2]	0.389	545	3.4	25	7.1
Gabon	1.3	16	4263	31	60 [1]	0.729	344	3.4 [6]	24	264.6
Ghana	23	51	294	21	40.8 [2]	0.533	435	4	51	18.9
Guinea	9.2	67	406	3	39	0.423	79	3	18	8.6
Kenya	36.6	79	439	4	42.5 [2]	0.532	27	3.6	26	0.7
Lesotho	2	76	528	1	63.2 [2]	0.496	78	3.5	36	39.0
Madagascar	19.2	71	238	10	47	0.533	85	3.7	39	4.4
Malawi	13.6	82	145	2	39	0.457	6	3.4	49	0.4
Mali	12	69	290	3	40	0.392	82	3.7	69	6.8
Mauritania	3	59	483	3	39	0.557	117.8 [5]	3.4	62	39.3
Mozambique	21	65	330	1	47	0.366	153	3.6	77	7.3
Namibia	2	64	2166	10	74.3 [2]	0.634	5	4 [6]	71	2.5
Nigeria	144.7	53	454	35	44	0.499	2,013	3.4	79	13.9
Rwanda	9.5	82	263	1	47	0.435	26	3.7	62	2.7
Senegal	12.1	58	499	19	41	0.502	64	3.7	68	5.3
South Africa	47.4	40	3,562	50 [3]	58	0.67	-6719	4 [6]	15	**-141.8** [9]
Tanzania	39.5	75	339	2	35	0.503	474	3.9	46	12.0
Uganda	29.9	87	274	3	41	0.493	393	3.9	52	13.1
Zambia	11.7	65	371	3	51	0.453	616	3.5	122	52.6

where

1) Based on Global Peace Index at http://en.wikipedia.org/wiki/List_of_countries_by_income_equality, Accessed 15 July 2009
2) UN Human Development Report 2007/2008, Table 15
3) http://www.mbendi.com/indy/powr/af/sa/p0005.htm, Accessed on 15 July 2009
4) UN Human Development Report 2007/2008, 12.9 percent of GDP at 2005, GDP = $5,500 millions at 2005
5) UN Human Development Report 2007/2008, 6.2 percent of GDP at 2005, GDP = $1,900 millions at 2005
6) The World Bank's IDA Resource Allocation Index (IRAI) is based on the results of the annual CPIA exercise that covers the IDA eligible countries. The CPIA rates countries against a set of 16 criteria grouped in four clusters: (a) economic management; (b) structural policies; (c) policies for social inclusion and equity; and (d) public sector management and institutions. The criteria are focused on balancing the capture of the key factors that foster growth and poverty reduction, with the need to avoid undue burden on the assessment process. To fully underscore the importance of the CPIA in the IDA Performance Based Allocations, the overall country score is referred to as the IRAI. Gabon, Namibia and South Africa are not included in the CPIA assessments. Thus values were estimated for these countries based on a comparison with other countries in the programme, on the scores for indices under 'Capable states' e.g. corruption perception index, control of corruption, government effectiveness, regulatory law and so on.
7) FDI per capita data calculated from FDI and population values
8) Values are displayed as 0 or 0.0 (LDB-Africa-2008) when they are zero or the number is so small that it will round to zero in the display shown.
9) Since this is negative number it implies that South Africa invests more in other countries than the FDI it receives.

HDI defined in UN Human Development Report 2007/2008, Technical Note 1 Addendum as the summary measure based on three basic dimensions of human development: Life expectancy at birth, as an index of population health and longevity; Knowledge and education, as measured by the adult literacy rate; Standard of living, as measured by the natural logarithm of GDP per capita. An index is created for each dimension. HDI is then calculated as a simple average of the dimension indices.

Table A.2: Ranking of residuals for the HDI and Y models

	HDI rank	Y rank
Nigeria	1	1
Congo, Rep	2	3
Ethiopia	3	9
Madagascar	4	2
Senegal	5	7
Cameroon	6	8
Uganda	7	4
Guinea	8	12
Malawi	9	5
Mali	10	19
South Africa	11	13
Namibia	12	11
Burkina Faso	13	20
Zambia	14	14
Kenya	15	6
Rwanda	16	15
Ghana	17	10
Lesotho	18	16
Benin	19	18
Mozambique	20	24
Gabon	21	17
Chad	22	23
Tanzania	23	22
Mauritania	24	21

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