Lightening the Path to Financial Development: The Power of Electricity

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Abstract

This paper examines the impact of access to electricity on financial development. In doing so, we use plausibly exogenous variations in population density as an instrument for electrification rate. Using panel data for 44 countries in Sub-Saharan Africa over the period 2000 to 2018, the results suggest that more people having access to electricity can promote financial development. In addition, mobile phone and commercial bank branches diffusion serve as potential channels through which access to electricity affects financial development. The results have important implications for policies in overcoming barriers to electricity access.

Keywords: Access to electricity; Financial development; Sub-Saharan Africa; Population density

JEL Codes: O16; Q43

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1 Introduction

Electricity is crucial for many aspects of the quality of life, such as poverty relief, economic growth and improving living standards. Hence, measuring the share of people with access to electricity (also known as electrification rate) is an important social and economic indicator. Lack of access to electricity is the ultimate economic hindrance because it prevents people from participating in the modern economy.

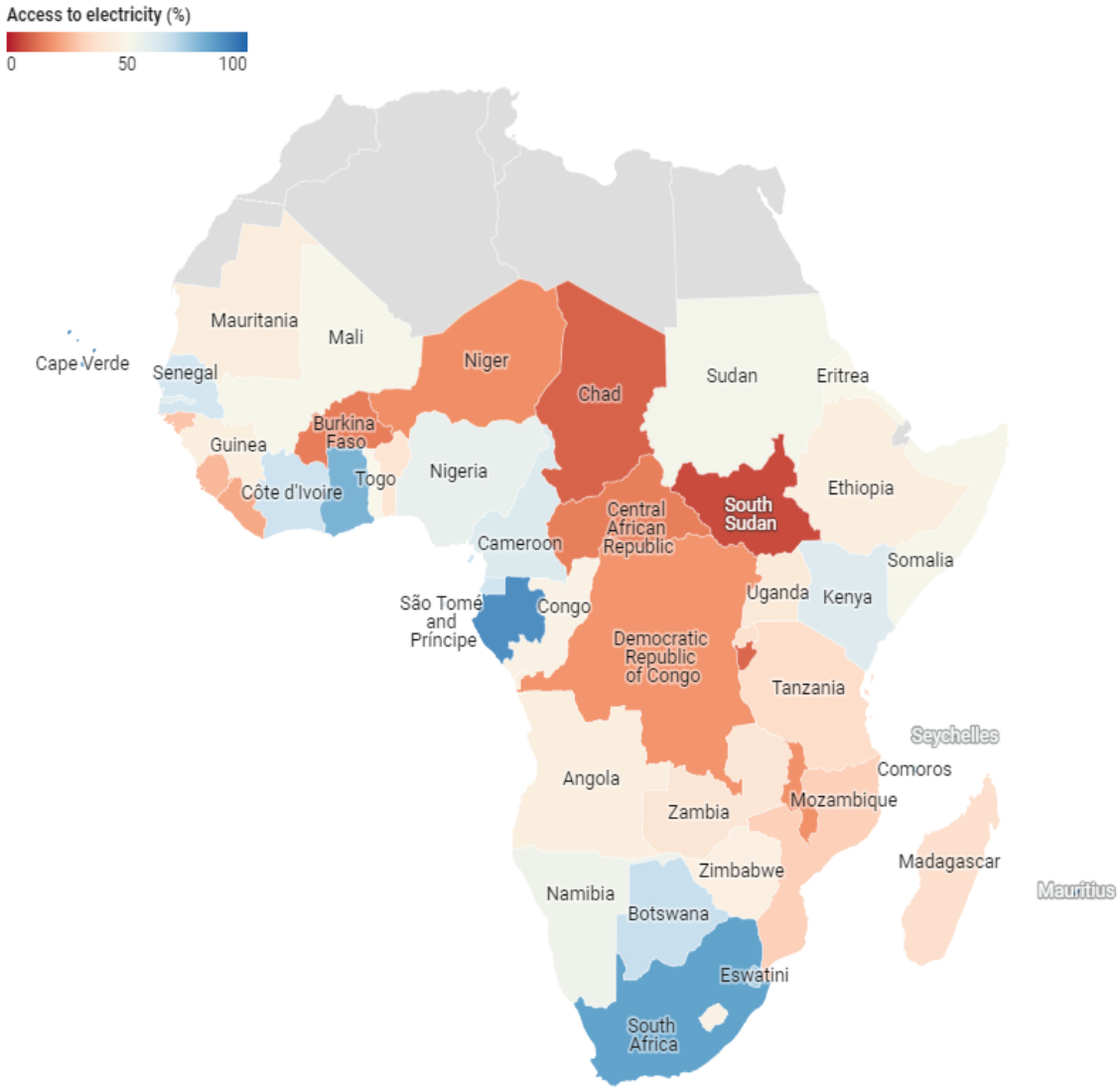
Previous studies have examined the effect of access to electricity (or energy poverty) on a number of social-economic variables, such as health (Awaworyi Churchill and Smyth, 2021; Pan et al., 2021), gender (Baruah, 2015) and education (Oum, 2019). Yet, there are almost no studies so far have investigated the impact of electrification rate on financial development. In addition, a major shortcoming is the lack of robust evidence on the effect of access to electricity using macro level data. Another issue is that the transmission channels through which electrification rate influences financial development remains a black box. In this paper, we aim at filling these empirical gaps in the literature.

We argue that the financial sector must be productive for the whole economy to develop and for which electricity is essential. Indeed, electricity can power the wheels of financial development in a country. Households demand residential electricity; and firms demand industrial and service electricity all in contribution to the growth of the economy. When there is higher electricity access rate, there is the likelihood for households to acquire and use new appliances hence demanding consumer credit from banks, while firms can expand their productive capacity or service delivery points demanding corporate financing from banks. Indeed, multinational companies are more likely to enter into countries where there is easy access to electricity to power their operations. Hence, the contribution of the inflow of direct foreign investment to the economy-especially the financial sector- of these destination countries cannot be overemphasized.

This is because increased demand for private credit by households and firms leads to increase in the development of the financial sector. Higher demand for private credit can also send a signal in attracting direct foreign investment into the financial sector further con-

tributing to financial development. Even for those firms (including financial institutions) that intend to expand their operations to remote areas, electricity is needed in order to operate smoothly in these areas. Especially, for financial technology (FinTech) firms, having an efficient and effective diffusion of their technology, requires electricity for their smooth operation and adoption (Armey and Hosman, 2016). It is therefore compelling to test empirically the impact of access to electricity on financial development.

Figure 1: Electrification rate in Sub-Saharan Africa (year 2018)



Note: Data is sourced from the World Development Indicators (WDI) database of World Bank.

In this regard, we examine this issue by looking at Sub-Saharan African countries. Sub-Saharan Africa has the largest share of people without electricity access (nearly two-thirds of the world population). Figure 1 presents electrification rate across Sub-Saharan countries

in the year 2018. It can be seen that more than half of the countries with electrification rate below 50%. Lack of electricity therefore is an urgent issue confined to the region. Moreover, although Sub-Saharan African countries have made substantial progress in financial development over the past decades, yet both financial markets and financial institutions are still far less developed than in other developing regions. Therefore, any factor that can significantly improve development prospects of the region is worth examining in detail.

This paper makes three key contributions. First, the study to the best of our knowledge is the first to examine the impact of electrification rate on financial development using cross-country panel data. Second, we use variations in population density as a novel instrumental variable (IV) for access to electricity. Thus, this paper documents for the first time to our knowledge, evidence on causal effect of electrification rate on financial development using an external instrument. The third contribution is to examine the possible channel through which access to electricity can impact financial development. We argue that the diffusion of technology, for instance, mobile phone penetration which has largely been used as information and communications technology (ICT) penetration indicator (Asongu et al., 2018) can serve as a potential mediator (channel) of the relationship between access to electricity and financial development. Indeed, technology is the basis for the appliances and equipment needed by households and the new machines and expansionary works of firms. Hence, it is electricity that is needed to power these new technologies. We therefore conjecture ICT to be the channel through which electricity access improves financial development. We also argue that diffusion of bank branches can be a potential channel through which access to electricity affect financial development. For banks to expand and diversify their loan portfolio, branch banking remains an essential ingredient. For this to be feasible, these branches will rely on the availability of basic amenities like electricity in areas where the branches will operate. This would enable the banks to efficiently provide all the services they offer across their network of branches. By so doing, the banking sector will see the needed growth and development.

The remainder of this paper proceeds as follows. Section 2 provides an overview of related literature. Section 3 presents the empirical strategies used in this study and describes the dataset. Section 4 discusses empirical findings. Section 5 performs mechanism analysis and Section 6 concludes with policy recommendations provided.

2 Literature Review

The issue of energy poverty has been on top of development agenda with the United Nations targeting (7th Goal of SDG) a universal access to affordable, reliable, sustainable and modern energy for all by 2030. This is because the development impact of access to electricity cannot be overemphasized with empirical studies documenting evidence of its impact on health (Awaworyi Churchill and Smyth, 2021; Pan et al., 2021), gender (Baruah, 2015), education (Oum, 2019), and productivity (Alam et al., 2020).

For instance, Oum (2019) look at how access to electricity affects education and health in Lao PDR. The study finds that low access to electricity is prevalent in households that have low income, are far from main roads and those living in villages. This phenomenon reduces the average school years of these households as well as their health status. Awaworyi Churchill and Smyth (2021), however, examine the impact of energy poverty on health in a developed nation – Australia. By looking at the requirement for energy for enough heating during cold winters and enough cooling during hot summers, they find that increases in energy poverty leads to decline in self-reported health of adult population in Australia.

Pan et al. (2021) in a global context also examine the effect of energy poverty on health. Using the system generalized method of moments (GMM) estimation and Oster's (2019) bound analysis, the authors find that energy poverty reduces public health and that higher standard of living in a country helps reduce the negative relationship. On the other hand, Baruah (2015) look at the opportunities in the renewable energy sector that can help improve the living standards of women in India. The author finds that there is great potential to improve access to technology and employment in energy sector of India through deliberate social policies that are gender inclusive: involves more women. A review of studies on energy poverty or access to electricity have generally focused on social economic outcomes such as education, gender and health.

There is however a lack of literature on the impact of access to electricity on financial development. Indeed, literature is not in dearth of the determinants of financial development. Variables such as education and economic growth (Calderón and Liu, 2003; Shahbaz

et al., 2018), trade (Newbery and Stiglitz, 1984; Rajan and Zingales, 2003), inflation (Bittencourt, 2011; Boyd et al., 2001), remittances, natural resources and political institutions (Bhattacharyya and Holder, 2014; Billmeier and Massa, 2009; Huang, 2010) have been explored in the previous studies.

Shahbaz et al. (2018) examine the determinants of financial development find that education, natural resources and economic growth improve financial development in the USA. Calderón and Liu (2003) in a similar study examine the relationship between financial development and growth and also find a positive link between financial development and economic growth. Similarly, Rajan and Zingales (2013) examine the determinant of financial development and find that, incumbent firms in trying to avoid competition oppose financial development, and that cross-border trade can help mitigate this negative impact in order to promote financial development. Bittencourt (2011) examine the effect of inflation on financial development in Brazil and find that inflation actually has a negative effect on financial development. Boyd et al. (2001) in an earlier study and in a broader context find similar results for a sample of 97 countries.

Bhattacharyya and Holder (2014) examine the impact of natural resources on financial development and find that natural resource revenue only has a positive impact on financial development when there are better political institutions. Billmeier and Massa (2009) using a panel of 17 emerging markets in the Middle East and Central Asia, find that both remittances and institutions improve financial development. Huang (2010) in a panel study of 90 developed and developing countries examine the impact of political institutions on financial development and find a positive impact especially in low-income countries.

The empirical review shows the existence of studies on electricity access and financial development albeit these studies have been done in isolation. Given the development impact of electricity access and financial development, we see the need to identify the exact relationship between these constructs in order to inform policy discussions; hence, the motivation of this study.

3 Methodology and Data

3.1 Empirical methodology

The specification of the baseline econometric model that relates financial development indicators and access to electricity is as below:

$$FD_{it} = \beta_0 + \beta_1 Electricity_{it} + \beta_2 \boldsymbol{X}_{it} + \varepsilon_{it} \tag{1}$$

where the subscript $i = 1,2,...,N$ stands for countries; $t = 1,2,...,T$ represents time period in years; FD_{it} refers to financial development indicators. In this paper, we use two main indicators related to banks. The first measure is private sector credit to GDP ratio, which is commonly accepted as one of the best indicators of financial development, and has been widely used in the literature (e.g. Levine, 1997; Ang and McKibbin, 2007). The second measure is broad money supply (M2) to GDP ratio, which has been used by King and Levine (1993) and many other studies. It is considered as the broadest measure of financial intermediation. $Electricity_{it}$ denotes electrification rate; $\boldsymbol{X}_{it}$ is a set of control variables that captures the common determinants of financial development such as trade openness, defined as the ratio of the sum of exports plus imports to total output; inflation measured by consumer price index (CPI); primary school enrolment; real GDP per capita; total natural resources rents as a share of of GDP; ratio of net foreign direct investment to GDP; remittances as percent of GDP and institutional quality composite index;[1] and ε_{it} is the idiosyncratic error term. The key regressor in the estimation is $Electricity_{it}$. As shown in the standard macro theory, electricity as an input of the production function drives the development of a country. Thus, we predict that $\beta_1 > 0$.

[1] We construct the composite index using principle component analysis (PCA) based on six widely used institutional quality measures. These indicators include rule of law, control of corruption, government effectiveness, political stability, absence of violence/terrorism, regulatory quality and voice, and accountability. In this study, we use the Kaiser (1974) and Jolliffe (2002) criterion who indicate that only common factors with an eigenvalue greater than one should be retained. Table A1 of Appendix presents the PCA results, and Table A2 reports correlation between the constructed institutional quality index and the six institutional quality indicators used.

We first use ordinary least squares (OLS) and fixed effect (FE) models to estimate Equation (1). Nevertheless, electrification rate is likely to be endogenous when estimating the relationship between access to electricity and financial development. Potential causes of endogeneity include reverse causality running from financial development to electrification rate (see Chen et al., 2012), and omitted variables given that it is impossible to control for all variables that can affect financial development.

To tackle the issue of endogeneity, we use an IV method as our main empirical strategy to pin down the causal effect of electrification rate on financial development. The cost differential between local governments to extend the electric grid from urban to rural areas may represent an exogenous variation in household electrification. Such a variation, as suggested by Grogan and Sadanand (2013), can be measured by population density within the geographical area of interest. Therefore, we use population density across countries as the primary instrument for access to electricity. The corresponding first-stage IV estimation regression is as below:

$$Electricity_{it} = \delta_0 + \delta_1 Popd_{it} + \phi \mathbf{X_{it}} + \mathbf{u_{it}} \tag{2}$$

where $Popd_{it}$ denotes population density; $\mathbf{X_{it}}$ is a vector of control variables in the structural regression; and u_{it} is stochastic error term. Having the predicted values of $\hat{Electricity}_{it}$, we estimate second-stage regression follows the same form as Equation (1).

3.2 Data

We use annual panel data for 44 countries (see list of countries in Table A3 of Appendix) spanning over the period 2000 to 2018. The institutional quality data are obtained from the World Governance Indicators (WGI), and all other data are sourced from the World Development Indicators (WDI) database of the World Bank. The summary statistics are presented in Table 1. It can be seen that there are large variations in the key variables across countries. The electrification rate ranges from 1.24% to 100%, suggesting that not all countries have equal access to electricity. Tremendous variations in financial development indicators are

also found across countries.

4 Results and Discussion

4.1 Preliminary analysis

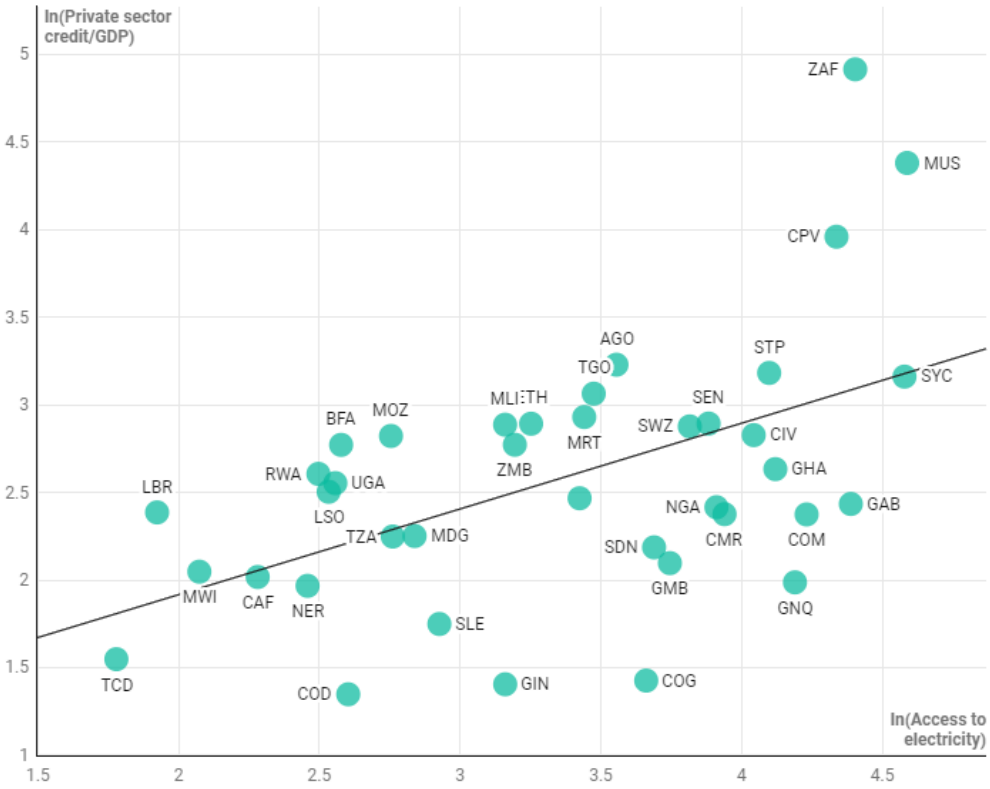
Prior to the regression analysis, we first provide some scatter diagrams as preliminary analysis. Panel A of Figure 2 suggests that there is a positive correlation between access to electricity and private sector credit to GDP ratio, and Panel B illustrates a positive relationship between electrification rate and M2 to GDP ratio. Overall, electrification rate is highly correlated with the two widely used financial development indicators, such that the fitted lines show very strong uphill linear pattern.

Table 1: Summary statistics

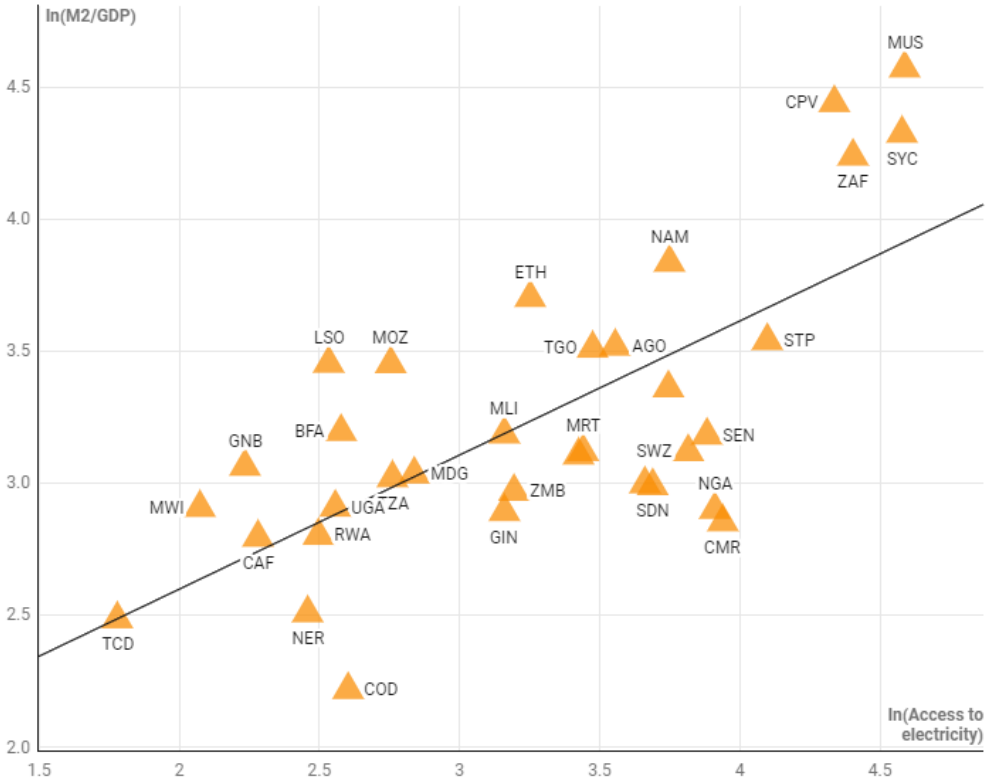
Variable	Obs.	Mean	Std.Dev	Min	Max
Domestic credit to private sector (% GDP)	585	21.74	26.48	0.49	160.12
Broad money (% GDP)	627	31.31	21.69	2.92	115.30
Access to electricity (% of population)	642	37.61	26.09	1.24	100
Trade (% of GDP)	609	72.55	35.47	19.1	225.02
Consumer price index (2010=100)	629	99.84	45.94	21.12	545.17
School enrolment, primary (% gross)	642	100.57	21.87	32.36	149.31
Real GDP per capita, PPP (constant 2011 international $)	642	4486.21	5277.41	630.70	36671.36
Total natural resources rents (% of GDP)	642	9.34	9.03	0.001	58.65
Foreign direct investment, net inflows (% of GDP)	533	0.64	3.43	-10.50	42.09
Personal remittances, received (% of GDP)	622	3.44	6.35	0	53.83
Institutional quality composite index	609	0.00	2.21	-4.41	5.38
Population density (people per sq. km of land area)	625	99.45	125.82	2.18	623.30
Mobile cellular subscriptions (per 100 people)	640	46.52	41.43	0.02	184.30
Commercial bank branches (per 100,000 adults)	496	6.86	9.78	0.30	54.36

Figure 2: Scatter plots of financial development indicators and access to electricity

Panel A: Private sector credit/GDP vs. Access to electricity



Panel B: M2/GDP vs. Access to electricity



4.2 Baseline results

We begin the empirical analysis with OLS estimation. Columns (1) and (2) of Table 2 show that the OLS estimate of the relationship between access to electricity and financial development is positive and statistically significant at the 1 percent level. However, one potential issue of OLS estimate is that the true effect of access to electricity on financial development may be inflated because not considering time-invariant variables with time-invariant effects. To overcome this issue, we use the FE estimator to control for time-invariant determinants of financial development. As shown in columns (3) and (4) of Table 2, the FE estimates yield mixed results for the impact of electrification rate on financial development, mainly due to potential endogeneity bias.

4.3 Main IV results

One drawback of FE estimate is that it cannot address the endogeneity issue that may arise from reverse causality, measurement error or omitted time-variant relevant variables. Therefore, it does not necessarily estimate the causal effect of electrification rate on financial development. To identify the causality from electrification rate to financial development, we rely on using an IV approach.

The second-stage results are presented in Tables 3a and 3b. In Column (1) of Table 3a, we regress private sector to GDP ratio on only access to electricity and trade openness, while other columns increasingly add more covariates concluding with Column (8) that includes the full set of controls. The results from Table 3a shows that, consistent with the theoretical prediction, there is a strong positive impact of access to electricity on private sector credit to GDP ratio. Such effect is not only statistically significant (at 1 the percent level in all regressions), it is also economically significant that, a 1 percent increase in electrification rate can lead to an increase in private sector to GDP ratio of about 0.58 percent to 1.11 percent depending on the exact specification. These results are consistent with the conjecture that endogeneity is causing a downward bias in the FE estimates.

To ascertain the robustness of our results on the relationship between electrification rate

Table 2: Access to electricity and financial development, OLS and FE regressions

	OLS		FE	
	(1) ln(Private sector credit/GDP)	(2) ln(M2/GDP)	(3) ln(Private sector credit/GDP)	(4) ln(M2/GDP)
ln(Access to electricity)	0.347***	0.236***	0.292***	0.114
	(0.049)	(0.038)	(0.081)	(0.093)
ln(Trade openness)	0.288***	0.274***	0.303***	0.242**
	(0.067)	(0.049)	(0.102)	(0.096)
ln(Consumer price index)	0.151***	0.087***	-0.274**	-0.165*
	(0.046)	(0.033)	(0.116)	(0.093)
ln(School)	0.570***	0.475***	0.084	0.183
	(0.115)	(0.087)	(0.199)	(0.242)
ln(Real GDP per capita)	0.401***	0.109*	0.569**	-0.186
	(0.101)	(0.064)	(0.258)	(0.229)
ln(Natural resources)	-0.005	-0.035*	-0.009	0.018
	(0.030)	(0.021)	(0.034)	(0.039)
FDI	0.003	-0.0004	-0.0004	-0.003
	(0.005)	(0.004)	(0.003)	(0.004)
Remittance	-0.013**	0.002	-0.012*	0.001
	(0.006)	(0.004)	(0.006)	(0.006)
Institutional quality	0.035	0.033**	0.021	0.034
	(0.021)	(0.015)	(0.033)	(0.032)
Country FE	No	No	Yes	Yes
Year FE	No	No	Yes	Yes
R^2	0.45	0.65	0.44	0.12
Obs.	435	459	435	459
No. of countries	38	38	38	38

Note: For columns (3) and (4), robust standard errors are in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Table 3a: Main IV results (private sector credit/GDP as dependent variable)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Access to electricity)	0.746***	0.656***	0.578***	0.626***	0.734***	0.866***	0.992***	1.114***
	(0.189)	(0.174)	(0.176)	(0.171)	(0.183)	(0.172)	(0.186)	(0.207)
ln(Trade openness)	0.245**	0.281***	0.272***	0.273***	0.340***	0.375***	0.295***	0.310***
	(0.095)	(0.095)	(0.088)	(0.089)	(0.091)	(0.096)	(0.071)	(0.083)
ln(Consumer price index)		-0.204***	-0.183***	-0.208***	-0.226***	-0.303***	-0.331***	-0.361***
		(0.062)	(0.069)	(0.074)	(0.072)	(0.077)	(0.069)	(0.080)
ln(School)			0.141	0.127	0.157	0.156	0.090	0.074
			(0.132)	(0.133)	(0.134)	(0.138)	(0.122)	(0.141)
ln(Real GDP per capita)				0.166	0.093	0.686***	0.625***	0.589***
				(0.151)	(0.157)	(0.156)	(0.167)	(0.198)
ln(Natural resources)					-0.137***	-0.100***	-0.090***	-0.094**
					(0.036)	(0.034)	(0.034)	(0.037)
FDI						-0.009*	-0.011*	-0.015**
						(0.005)	(0.006)	(0.007)
Remittance							-0.022**	-0.023*
							(0.010)	(0.012)
Institutional quality								0.015
								(0.029)
First-stage regressions								
Population density	1.259***	1.291***	1.389***	1.529***	1.432***	1.726***	1.645***	1.726***
	(0.244)	(0.247)	(0.309)	(0.369)	(0.364)	(0.346)	(0.324)	(0.355)
Adjusted R^2	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Durbin χ^2-test	11.39***	7.43***	5.01**	8.10***	10.34***	16.98***	25.29***	35.04***
Wu-Hausman F-test	10.30***	6.64**	4.44**	7.21***	9.23***	15.13***	22.98***	32.46***
1st-stage F-test	26.71***	27.37***	20.30***	17.29***	15.55***	25.19***	26.30***	24.23***
R^2	0.93	0.94	0.94	0.94	0.93	0.94	0.93	0.93
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	537	526	526	526	526	450	448	428
No. of countries	41	41	41	41	41	38	37	37

Note: Robust standard errors are in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

and financial development, we also use an alternative measure of financial development. As can be seen in Table 3b, the coefficients on access to electricity are positive and statistically significant at 1 the percent level in all regressions, confirming the robustness of our main findings that higher electrification rate enhances financial development.

Trade openness and CPI are the other two variables that significantly affect financial development. Tables 3a and 3b show that greater trade openness brings higher level of financial development. This finding is consistent with previous studies following Newbery and Stiglitz (1984) and Rajan and Zingales (2003) who find that trade has a beneficial influence on financial development. In contrast, the results in Tables 3a and 3b suggest that high rates of inflation negatively affect developments of financial sector. The finding is also in line with a large body of empirical works (e.g. Boyd et al., 2001; Bittencourt, 2011) that has found that inflation affects financial development negatively.

The first-stage regression outcome is also reported in Tables 3a and 3b. The coefficients of population density are highly statistically significant at the 1 percent level, with the anticipated sign. Individuals residing in locations with higher population density are more likely to have access to electricity. Furthermore, the first-stage F-test statistics are well above 10. Another critical identifying assumption is that the instrumental variable is uncorrelated with the second-stage regression errors, so that variations in population density can be utilised as an exclusion restriction in the IV estimates. Because our model is exactly identified, the Sargan test for over-identification restrictions cannot be calculated. Therefore, we follow the approach proposed by Altonji et al. (2005). Specifically, we test the exogeneity assumption by examining the sensitivity of the estimates to the inclusion and exclusion of control variables. The incremental addition of controls across columns (1) to (8) in Tables 3a and 3b indicate that the IV estimates are not sensitive to the inclusion and exclusion of covariates. These results suggest that population density is sufficiently correlated with electrification rate to serve as a potentially good instrument. In addition, we also examine whether access to electricity is exogenous. Both the statistics of the Durbin and Wu-Hausman tests are highly significant, suggesting that access to electricity is endogenous.

Table 3b: Main IV results (M2/GDP as dependent variable)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Access to electricity)	0.657***	0.632***	0.521***	0.435***	0.456***	0.683***	0.723***	0.761***
	(0.167)	(0.164)	(0.152)	(0.145)	(0.149)	(0.164)	(0.170)	(0.180)
ln(Trade openness)	0.220***	0.222***	0.207***	0.213***	0.234***	0.266***	0.230***	0.249***
	(0.066)	(0.068)	(0.063)	(0.058)	(0.058)	(0.065)	(0.060)	(0.064)
ln(Consumer price index)		-0.247***	-0.218***	-0.158***	-0.162***	-0.231***	-0.246***	-0.225***
		(0.048)	(0.045)	(0.044)	(0.044)	(0.050)	(0.048)	(0.053)
ln(School)			0.233**	0.233***	0.250***	0.215**	0.180*	0.192
			(0.091)	(0.088)	(0.088)	(0.105)	(0.103)	(0.120)
ln(Real GDP per capita)				-0.418***	-0.438***	-0.021	-0.042	-0.169
				(0.098)	(0.099)	(0.123)	(0.128)	(0.162)
ln(Natural resources)					-0.042	-0.051*	-0.046	-0.037
					(0.026)	(0.031)	(0.031)	(0.032)
FDI						-0.010	-0.011*	-0.014**
						(0.006)	(0.006)	(0.007)
Remittance							-0.008	-0.009
							(0.011)	(0.012)
Institutional quality								0.032
								(0.024)
First-stage regressions								
Population density	1.293***	1.290***	1.393***	1.483***	1.431***	1.760***	1.679***	1.758***
	(0.230)	(0.234)	(0.276)	(0.311)	(0.305)	(0.329)	(0.308)	(0.334)
Adjusted R^2	0.94	0.94	0.94	0.94	0.95	0.94	0.94	0.94
Durbin χ^2-test	27.88***	26.39***	18.64***	13.34***	13.58***	28.49***	31.35***	35.65***
Wu-Hausman F-test	26.16***	24.60***	17.09***	12.09***	12.29***	26.22***	29.02***	33.22***
1st-stage F-test	31.74***	30.58***	25.68***	22.83***	22.12***	29.12***	30.23***	28.23***
R^2	0.89	0.90	0.92	0.93	0.93	0.91	0.91	0.91
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	579	566	566	566	566	474	472	452
No. of countries	41	41	41	41	41	38	37	37

Note: Robust standard errors are in parentheses. *, ** and *** indicate statistical significance at the 10%, 5% and 1% levels, respectively.

4.4 Robustness checks

In this section, we conduct three sets of sensitivity checks. First, we estimate the baseline model with the IV strategy developed by Lewbel (2012). Second, we divide the data sample into multiple time periods to examine whether business cycle shocks can affect the impact of access to electricity on financial development. Third, we divide our sample into two sub-samples based on country income.

4.4.1 Lewbel (2012) heteroskedasticity-based identification

To check the robustness of the results, we augment the external instrument with heteroskedasticity-based instruments constructed using Lewbel's (2012) approach. According to Lewbel (2012), the constructed instrument based on heteroskedasticity can be used when there is a lack of external IVs and for testing the validity of external instruments. The Lewbel's (2012) approach is briefly described as below:

$$Y_1 = \boldsymbol{X}'\beta + Y_2\gamma + \varepsilon_1, \quad Y_2 = \boldsymbol{X}'\alpha + \varepsilon_2 \tag{3}$$

where ε_1 and ε_2 are the error terms; Y_1 stands for the dependent variable which is the financial indicators in this case; Y_2 refers to the endogenous variable (i.e. access to electricity) and $\boldsymbol{X}$ denotes the vector of control variables. One important issue is that it is likely to be that no element of $\boldsymbol{X}$ is excluded from the Y_1 equation, or it could be the case that any element β is zero. To deal with this issue, Lewbel (2012) develops an identification strategy based on two-stage least-squares (2SLS) estimator when there are no suitable external instruments for the endogenous variable, Y_2, by exploiting information contained in heteroskedasticity of ε_2. The model of Lewbel (2012) has the standard assumption of non-singularity of matrix $E(\boldsymbol{X}\boldsymbol{X}')$ and $E(\boldsymbol{X}\varepsilon_1) = E(\boldsymbol{X}\varepsilon_2) = 0$. Furthermore, β and γ are assumed to be constants. Notice that the Lewbel (2012) estimator requires the following crucial assumptions hold. That is, $Cov(\boldsymbol{Z}, \varepsilon_1, \varepsilon_2) = 0$ and $Cov(\boldsymbol{Z}, \varepsilon_2^2) \neq 0$, and $\boldsymbol{Z} = \mathbf{X}$ or $\boldsymbol{Z}$ is a subset of the elements of $\boldsymbol{X}$. After estimating α and getting the residual from OLS regression of Y_2 on $\boldsymbol{X}$, β and γ can be obtained using 2SLS estimation using $\boldsymbol{X}$ and $(\boldsymbol{Z} - \bar{\boldsymbol{Z}})\hat{\varepsilon}_2$ as instruments, where $\bar{\boldsymbol{Z}}$ stands for

the mean of $\boldsymbol{Z}$.

The Lewbel (2012) IV estimates are reported in Table 4. Columns (1) and (2) present the IV estimates results using the constructed instruments, while columns (3) and (4) report the estimates using external instruments augmented by the constructed instruments. The results clearly show that the coefficient of access to electricity remains statistically significant at the 1 percent level in all regressions, confirming the positive impact of electrification rate on financial development. The results of Table 4 also show that FDI has a positive and significant effect on financial development. This is consistent with the well-documented stylized fact that FDI is an important source of development. Furthermore, institutional quality is another factor that influences financial development. This is also in line with Billmeier and Massa (2009) that good quality institutions are the main drivers of financial development and it stimulates financial development.

4.4.2 Dividing sample into multiple time periods

We further examine the robustness of the results by split the data sample into different time periods. This is to check whether the influence of access to electricity on financial development will vary when global economic or financial conditions have changed. In the data sample, there are at least three negative shocks that affect the financial sector development: the 2000 Dotcom bubble, the 2007-2009 global financial crisis (GFC) and the 2010-2012 European debt crisis. Hence, we divide the data sample into two periods: non-crisis period (2001-2006, 2013-2018) and crisis period (2000, 2007-2012). The regression results are reported in Table 5. It can be seen that the main results on how access to electricity affects financial development still holds, that is, electrification rate has a positive causal effect on financial development. Moreover, such effect is smaller in crisis period.

4.4.3 Dividing sample into different income groups

One may concern that low-income countries are likely to be financially less developed than middle- and high-income countries. The baseline regression results may not be precise without considering such difference. Therefore, we divide our sample into two subsamples

Table 4: Access to electricity and financial development, Lewbel (2012) IV estimates

	Generated IV		Generated and External IV	
	(1) Private sector credit/GDP	(2) M2/GDP	(3) Private sector credit/GDP	(4) M2/GDP
ln(Access to electricity)	0.470***	0.298***	0.376***	0.332***
	(0.117)	(0.080)	(0.112)	(0.072)
ln(Trade openness)	-0.068	0.254***	-0.052	0.287***
	(0.098)	(0.056)	(0.097)	(0.056)
ln(Consumer price index)	0.034	-0.273***	0.053	-0.236**
	(0.144)	(0.101)	(0.143)	(0.100)
ln(School)	-0.038	0.025	-0.034	0.047
	(0.117)	(0.086)	(0.115)	(0.084)
ln(Real GDP per capita)	-0.007	-0.029	0.055	-0.072
	(0.114)	(0.070)	(0.111)	(0.065)
ln(Natural resources)	-0.017	-0.056***	-0.016	-0.055***
	(0.026)	(0.013)	(0.026)	(0.013)
FDI	0.030***	0.013**	0.033***	0.011*
	(0.010)	(0.006)	(0.010)	(0.006)
Remittance	0.002	0.005	0.003	0.004
	(0.006)	(0.003)	(0.006)	(0.003)
Institutional quality	0.182***	0.111***	0.187***	0.120***
	(0.020)	(0.013)	(0.021)	(0.013)
R^2	0.61	0.74	0.62	0.74
Obs.	435	459	428	452
No. of countries	38	38	37	37
Hansen J stat	35.11	42.02	36.25	43.43
Hansen J p-value	0.07	0.01	0.07	0.01

Note: Robust standard errors in the parenthesis. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 5: OLS regression (divide sample into multiple periods)

	Non-crisis period		Crisis period	
	(1)	(2)	(3)	(4)
	Private sector credit/GDP	M2/GDP	Private sector credit/GDP	M2/GDP
ln(Access to electricity)	0.457***	0.406***	0.282***	0.182***
	(0.067)	(0.058)	(0.095)	(0.058)
ln(Trade openness)	0.415***	0.299***	0.040	0.161**
	(0.076)	(0.062)	(0.116)	(0.074)
ln(Consumer price index)	0.198***	0.057	0.274***	0.165***
	(0.053)	(0.040)	(0.075)	(0.050)
ln(School)	0.618***	0.486***	0.659***	0.412***
	(0.138)	(0.117)	(0.185)	(0.119)
ln(Real GDP per capita)	0.248**	-0.036	0.171	0.110
	(0.118)	(0.080)	(0.142)	(0.080)
ln(Natural resources)	-0.0005	-0.036	-0.077	-0.060**
	(0.033)	(0.026)	(0.052)	(0.030)
FDI	0.020**	0.022***	0.006	0.0003
	(0.009)	(0.008)	(0.006)	(0.004)
Remittance	-0.022**	-0.006	-0.001	0.008*
	(0.010)	(0.008)	(0.008)	(0.005)
Institutional quality	0.043*	0.061***	0.071**	0.047**
	(0.025)	(0.020)	(0.036)	(0.022)
R^2	0.49	0.66	0.54	0.71
Obs.	251	261	184	198
No. of countries	37	37	36	38

Note: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

based on the World Bank country classifications: low-income countries and middle-income countries[2]. Results are presented in Table 6. We can see that in both of the two submsamples, the coefficients on access to electricity are all positive, and are also statistically significant at the 5 percent level or better, which is consistent with the baseline OLS regression results.

5 Mechanisms

In this section, we examine whether mobile phone and bank branches diffusion and can serve as potential channels through which access to electricity impacts financial development. We use mobile cellular subscriptions per 100 people and commercial bank branches per 100,000 adults as measurements for mobile phone diffusion and bank branches diffusion, respectively. As argued in Jensen (2007), mobile phone use can promote market efficiency, and thus lead to a more prosperous financial market. More importantly, mobile phone development can bring to financial development, in particular through enhancing financial inclusion. In Africa, a large percentage of population are using informal finance or financially excluded. Mobile phone diffusion therefore is a powerful way to overcome financial infrastructure gap in Africa. In fact, branchless banking services, such as mobile financial services (e.g. mobile money), are more and more popular in Africa. According to the Global System for Mobile Communications Association (GSMA, 2019), as of December 2018, two-thirds of global mobile money transactions are driven by users in Sub-Saharan Africa.

On the other hand, bank branches are likely to be set up in areas where there is access to electricity. Moreover, expansion of banking business through branch banking leads to higher financial development as banks reach the unbanked and financially excluded. Given the ability of banks to mobilize fresh savings through the new branches and offer financial services through same, banks are able to expand their credit hence lead to the development of the financial sector.

[2]World Bank splits middle-income countries into two categories: upper-middle-income nations and lower-middle-income nations.

Table 6: OLS regression (divide sample into different income groups)

	Low-income countries		Middle-income countries	
	(1)	(2)	(3)	(4)
	Private sector credit/GDP	M2/GDP	Private sector credit/GDP	M2/GDP
ln(Access to electricity)	0.190***	0.098**	0.538***	0.351***
	(0.073)	(0.048)	(0.096)	(0.075)
ln(Trade openness)	0.149	0.213**	0.286***	0.261***
	(0.133)	(0.088)	(0.081)	(0.062)
ln(Consumer price index)	0.292***	0.126**	-0.114	0.063
	(0.084)	(0.052)	(0.074)	(0.053)
ln(School)	0.352**	0.450***	0.491***	0.089
	(0.161)	(0.107)	(0.181)	(0.147)
ln(Real GDP per capita)	0.959***	0.629***	0.731***	0.150
	(0.221)	(0.150)	(0.157)	(0.105)
ln(Natural resources)	0.196**	0.085	-0.057*	-0.028
	(0.086)	(0.057)	(0.031)	(0.022)
FDI	0.005	0.002	0.012	0.004
	(0.007)	(0.004)	(0.013)	(0.010)
Remittance	-0.005	0.004	-0.008	0.009
	(0.010)	(0.007)	(0.007)	(0.006)
Institutional quality	0.080**	0.038*	0.017	0.049**
	(0.033)	(0.021)	(0.030)	(0.022)
R^2	0.36	0.44	0.53	0.66
Obs.	171	176	246	265
No. of countries	15	15	22	22

Note: *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 7: Effect of access to electricity on the potential channels

Dependent Variable	Mobile cellular subscriptions	Number of bank branches
ln(Access to electricity)	0.655***	0.253***
	(0.125)	(0.060)
Controls	Yes	Yes
R^2	0.61	0.68
Obs.	466	402

Note: *** indicates statistical significance at the 1% level.

To examine whether mobile phone and bank branches diffusion qualify as potential channels through which electrification rate to financial development, we follow the approach in the previous studies such as Alesina and Zhuravskaya (2011) and Ackermann et al. (2021). Two conditions need to be satisfied for mobile phone use and number of bank branches to qualify as potential channels. First, mobile cellular subscriptions and number of bank branches need to be correlated with access to electricity. Table 7 reports results for the impact of access to electricity on the two potential channels. The results suggest that getting access to electricity is associated with an increase in the usage of mobile phone and number of bank branches. In particular, access to electricity is associated with a 0.66 percent and 0.25 percent increase in mobile cellular subscriptions and number of commercial bank branches, respectively.

The second condition is including mobile cellular subscriptions or number of bank branches as an additional control variable in the regression relates electrification rate and financial development indicators should decrease the scale of the coefficient on electrification rate or render it insignificant. Tables 8 presents the results. Columns (2), (3), (5) and (6) show that when mobile cellular subscriptions or number of bank branches is added as an additional control variable, the scale of the coefficient on access to electricity decreases. The findings suggest that mobile phone and bank branches diffusion are potential channels through which access to electricity transmits to financial development.

Table 8: Effect of access to electricity and the potential channels on financial development

Dependent Variable	Private sector credit/GDP			M2/GDP		
	(1)	(2)	(3)	(4)	(5)	(6)
Access to electricity	0.347***	0.252***	0.235***	0.236***	0.167***	0.138***
	(0.049)	(0.047)	(0.047)	(0.038)	(0.037)	(0.036)
Mobile cellular subscriptions		0.128***			0.090***	
		(0.016)			(0.012)	
Number of bank branches			0.466***			0.262***
			(0.040)			(0.030)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	435	433	373	459	457	395
R^2	0.45	0.51	0.54	0.65	0.72	0.73

Note: *** indicates statistical significance at the 1% level.

6 Conclusion and Policy Recommendations

This paper investigates the impact of access to electricity on financial development in Sub-Saharan Africa. To do so, we utilise variations in population density as an instrument for electrification rate. To our knowledge, this is the first study to adopt IV approach using a plausibly exogenous source of variations as an identification strategy to identify the causal effect of electrification rate on financial development. The findings from the IV regression suggest that higher electrification rate is beneficial to financial development. In addition, mobile phone and commercial bank branches diffusion are potential channels that underpins the relationship between access to electricity and financial development.

On the policy front, governments need to understand that demand-related factors account for the largest percentage of electricity access gap in Sub-Saharan Africa. Since most households in the region cannot afford to connect and pay tariffs that will allow electricity to consume at meaningful levels, greater electricity access requires lower electricity prices. One issue is that although lower regulated tariffs can make electricity access more affordable, it may also exacerbate the financial stress on the utilities. Hence, the optimal solution to make electricity more affordable for households and improve the financial viability of utility service providers at the same time is to focus on using electricity mainly for income generating activities. To be more specific, governments can help the financial viability of utilities through higher consumption and feed back into the public finances through taxes for rein-

vestment. Moreover, governments should take advantage of technological advances in off-grid solutions to strategically promote productive electricity uses, especially in rural areas. More importantly, policy makers need to recognise electrification as a necessary, long-term investment for economic transformation. Any plans that aims to increase access to electricity should not be evaluated based only on short-term benefits, which are unlikely to cover its costs. It is important to finance the upfront costs in a time-consistent way.

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Appendix A: Additional Results

Table A1: Principal Component Analysis of Institutional quality

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	4.88249	4.45249	0.8137	0.8137
Comp2	0.429996	0.120825	0.0717	0.8854
Comp3	0.309171	0.0983046	0.0515	0.9369
Comp4	0.210867	0.118682	0.0351	0.9721
Comp5	0.0921852	0.0168945	0.0154	0.9875
Comp6	0.0752906	-	0.0125	1

A correlation matrix in Table A2 between the Institutional quality index and the six variables are shown. While we see high correlation among the six quality indicators ranging from 63% to 90%, The institutional quality index from the PCA shows a higher correlation between the variables from 83% to 97%, showing that the index appropriately represents the six institutional quality indicators.

Table A2: Correlation matrix of Institutional quality index and six governance indicators

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Institutional Quality Index (PCA)	1						
(2) Control of Corruption	0.918	1					
(3) Govoernment effectiveness	0.9347	0.854	1				
(4) Political Stability	0.8305	0.7366	0.6737	1			
(5) Rule of Law	0.9667	0.8812	0.9014	0.782	1		
(6) Regulatory quality	0.8982	0.7595	0.8843	0.6347	0.8529	1	
(7) Voice and Accountability	0.8573	0.7231	0.723	0.6911	0.8005	0.7138	1

Appendix B: Data Appendix

This appendix provides the list of countries used in the study.

Table A3: List of countries

Country	World Bank Country code	Country	World Bank Country code
Angola	AGO	Benin	BEN
Burkina Faso	BFA	Botswana	BWA
Central Africa Rep.	CAF	Cote d'Ivoire	CIV
Cameroon	CMR	Congo, Dem.Rep.	COD
Congo, Rep.	COG	Comoros	COM
Cabo Verde	CPV	Ethiopia	ETH
Gabon	GAB	Ghana	GHA
Guinea	GIN	Gambia	GMB
Guinea-Bissau	GNB	Equatorial Guinea	GNQ
Kenya	KEN	Liberia	LBR
Lesotho	LSO	Madagascar	MDG
Mali	MLI	Mozambique	MOZ
Mauritania	MRT	Mauritius	MUS
Malawi	MWI	Nambia	NAM
Niger	NER	Nigeria	NGA
Rwanda	RWA	Sudan	SDN
Senegal	SEN	Sierra Leone	SLE
São Tomé and Príncipe	STP	Eswatini	SWZ
Seychelles	SYC	Chad	TCD
Togo	TGO	Tanzania	TZA
Uganda	UGA	South Africa	ZAF
Zambia	ZMB	Zimbabwe	ZWE