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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 a number of instrumental variables (IV) approaches. Using panel data for 38 countries in Sub-Saharan Africa over the period 2000–2018, 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. Our results are robust to sample-splitting and different estimation techniques. The results have important implications for policies in overcoming barriers to electricity access.

KEYWORDS

access to electricity, financial development, slope of terrain, Sub-Saharan Africa

JEL CLASSIFICATION

O16, Q43

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 the 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 & Smyth, 2021; Pan et al., 2021), gender (Baruah, 2015), education (Oum, 2019), employment (Dinkelman, 2011), industrial development (Rud, 2012), and productivity (Alam et al., 2018). For instance, Oum (2019) investigates 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 lead to decline in the self-reported health of the 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) looks 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 has generally focused on social–economic outcomes such as education, gender, and health.

There are almost no studies so far that 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 a 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 an 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 contributing 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 & Hosman, 2016). It is therefore compelling to test empirically the impact of access to electricity on financial development. Indeed, previous studies have identified the determinants of financial development to include: education and economic growth (Calderón & Liu, 2003; Shahbaz et al., 2018), trade (Rajan & Zingales, 2003), inflation (Bittencourt, 2011; Boyd et al., 2001), natural resources and institutions (Bhattacharyya & Hodler, 2014; Billmeier & Massa, 2009; Huang, 2010) with no study looking at the role of electrification in the development of the financial sector.

Given these issues, we examine this relationship 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 the 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

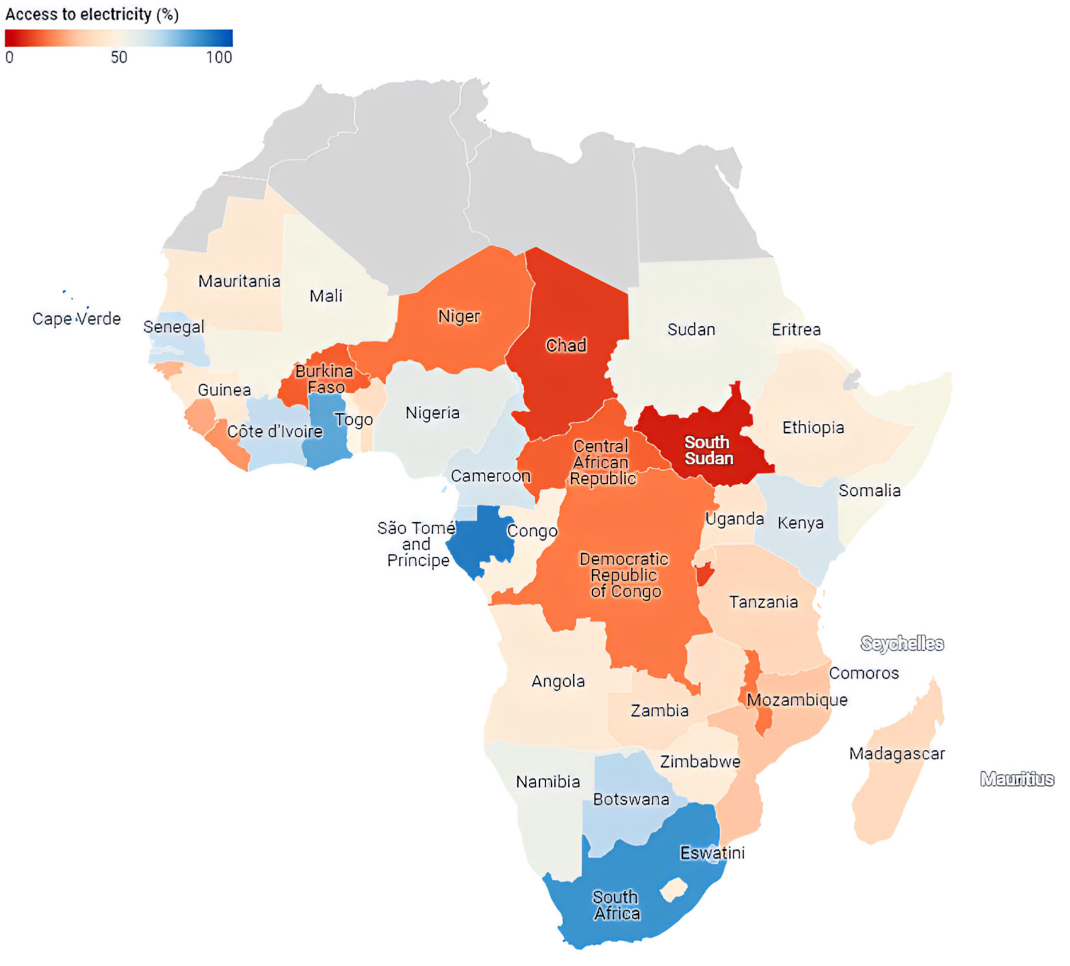

FIGURE 1 Electrification rate in Sub-Saharan Africa (year 2018). Data are sourced from the World Development Indicators (WDI) database of the World Bank.

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 the development prospects of the region is worth examining in detail.

As shown in Figure 2, the electrification rate has a positive correlation with financial development (private sector credit to GDP ratio) such that the fitted line shows very strong uphill linear pattern; hence, higher access to electricity can be the potential factor to improve financial development. It is therefore important to empirically test this relationship.

This paper makes three key contributions. First, the study, to the best of our knowledge, is to examine the impact of electrification rate on financial development using cross-country panel data. Second, we use average slope of the country's surface area 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 channels 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

FIGURE 2 Private sector credit/GDP versus access to electricity.

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 the diffusion of bank branches can be a potential channel through which access to electricity affects 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.

Our results show that higher electrification rate increases financial development. We confirm our hypothesis that ICT and bank branch diffusion are channels through which access to electricity impacts financial development. We show that these results are robust to sample-splitting, additional control variables, and different estimation techniques.

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

2 | METHODOLOGY AND DATA

2.1 | Empirical methodology

The specification of the baseline econometric model that relates financial development indicator 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 $i = 1, 2, \ldots, N$ stands for countries; $t = 1, 2, \ldots, T$ represents time period in years; FD_{it} refers to financial development indicator. In this paper, we use the indicator related to banks as a proxy for financial development. Specifically, the 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. Ang & McKibbin, 2007; Levine, 1997). $Electricity_{it}$ denotes electrification rate which is measured as the percentage of population with access to electricity; $\boldsymbol{X}_{it}$ 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 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 $\beta_1 > 0$.

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. Furthermore, the macroeconomics literature acknowledges that infrastructure could be targeted toward growing areas. Such selection biases the comparison between electrified and non-electrified areas, and in unpredictable ways. To tackle the issue of endogeneity, we use the IV method as our main empirical strategy to pin down the causal effect of electrification rate on financial development. More specifically, we use the average uphill slope of the country's surface area interacts with the financial crises as a shift-share instrument for electrification rate. Higher slope increases the average cost of a household electricity connection, making slope a key factor in prioritizing areas for electrification. We argue that in the case of Sub-Saharan Africa, a region with poor agricultural prospects, land slope is unlikely to directly affect development outcomes. Yet, one may argue that slope could have a non-monotonic relationship with electrification due to its linkage with dams and sewerage (see e.g. Duflo & Pande, 2007). Another concern is that the average slope is not changing over time, thus using the cross-sectional variation to instrument for a time-varying variable might not be appropriate. To deal with all these issues, we interact average slope of land with the financial crises to build a shift-share instrument. We argue that the crises (i.e. Global Financial Crisis and European Debt Crisis) are exogenous to any factor specific to an African country in our sample given that the US and Europe are transmitters of shocks (Chen et al., 2014), while the African countries are open economies that receive shocks from the US and Europe. Therefore, interacting crisis dummy with slope provides justification for meeting the exogeneity condition of our IV. The corresponding first-stage IV estimation regression is as below:

[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 A presents the PCA results, and Table A2 reports correlation between the constructed institutional quality index and the six institutional quality indicators used.

TABLE 1 Summary statistics.

Variable	Mean	Std.dev	Min	Max
Domestic credit to private sector (% GDP)	24.96	29.02	2.01	160.12
Access to electricity (% of population)	42.38	27.18	1.24	100.00
Trade (% of GDP)	76.33	36.78	20.72	225.02
Consumer price index (2010 = 100)	100.28	32.92	21.12	305.03
School enrolment, primary (% gross)	102.14	21.33	32.36	149.31
Real GDP per capita, PPP (constant 2011 international $)	5051.30	5511.68	730.72	27996.77
Total natural resources rents (% of GDP)	8.55	8.47	0.00	58.65
Foreign direct investment, net inflows (% of GDP)	0.23	2.33	−10.50	32.70
Personal remittances, received (% of GDP)	3.35	4.85	0.00	37.94
Institutional quality composite index	0.35	2.22	−4.41	5.38
Average uphill slope of surface area (%)	2.43	3.70	0.31	17.60
Mobile cellular subscriptions (per 100 people)	54.89	43.00	0.02	184.30
Commercial bank branches (per 100,000 adults)	7.39	10.40	0.39	54.36

Note: The variables are denoted as follows: Domestic credit to private sector (% GDP) – Private sector credit/GDP; Access to electricity as is; Trade – Trade openness; Consumer price index (2010 = 100) – Consumer price index; School enrolment, primary (% gross) – School; Real GDP per capita, PPP (constant 2011 international $) – Real GDP per capita; Total natural resources rents (% of GDP) – Natural resources; Foreign direct investment, net inflows (% of GDP) – FDI; Personal remittances, received (% of GDP) – Remittances; and Institutional quality composite index – Institutional quality; Average uphill slope of surface area (%) – Average slope of terrain; Mobile cellular subscriptions (per 100 people) – Mobile cellular subscriptions; Commercial bank branches (per 100,000 adults) – Commercial bank branches.

$$Electricity_{it} = \delta_0 + \delta_1 \left(Slope_i \times Crisis_{it} \right) + \phi \boldsymbol{X}_{it} + u_{it} \quad (2)$$

where $Slope_i$ denotes the average slope of terrain; $Crisis_{it}$ denotes the Global Financial Crisis and European Debt Crisis taking the value of one when crisis occurs and zero otherwise. $\boldsymbol{X}_{it}$ is a vector of control variables in the structural regression; and u_{it} is a stochastic error term. Having the predicted values of $\widehat{Electricity}_{it}$, we estimate second-stage regression follows the same form as Equation (1).

2.2 | Data

We use unbalanced annual panel data for 38 countries[2] (see list of countries in Table A3 of Appendix B) spanning over the period 2000–2018. The land slope and institutional quality data are obtained from Nunn and Puga (2012) and World Governance Indicators (WGI), respectively. 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. This provides a good sample given that the impact of the progress of higher electrification on financial development can be estimated. If higher electrification rate improves financial development, countries with low levels of electrification rate can as a matter of policy choose to improve their access to electricity as a way to improve their level of financial development. We also observe tremendous variations in private sector credit to GDP ratio across countries with a minimum of 2.01% share of GDP as domestic credit to the private sector. Again, these variations give a good sample to help estimate the role of electrification in the financial development process.

[2]Due to unavailability of data for our instrument (average slope of terrain) for some countries, the IV estimations comprised 26 countries.

TABLE 2 Access to electricity and financial development, OLS and FE regressions.

	OLS	FE
	(1)	(2)
	ln (Private sector credit/GDP)	ln (Private sector credit/GDP)
ln (Access to electricity)	0.347***	0.292***
	(0.049)	(0.081)
ln (Trade openness)	0.288***	0.303***
	(0.067)	(0.102)
ln (Consumer price index)	0.151***	−0.274**
	(0.046)	(0.116)
ln (School)	0.570***	0.084
	(0.115)	(0.199)
ln (Real GDP per capita)	0.401***	0.569**
	(0.101)	(0.258)
ln (Natural resources)	−0.005	−0.009
	(0.030)	(0.034)
FDI	0.003	−0.0004
	(0.005)	(0.003)
Remittances	−0.013**	−0.012*
	(0.006)	(0.006)
Institutional quality	0.035	0.021
	(0.021)	(0.033)
Country FE	No	Yes
Year FE	No	Yes
R^2	0.45	0.44
Obs.	435	435
No. of countries	38	38

Note: For column (2), robust standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

3 | RESULTS AND DISCUSSION

3.1 | Baseline results

We begin the empirical analysis with OLS estimation. Column (1) of Table 2 shows that the OLS estimate of the relationship between access to electricity and financial development is positive and statistically significant at the 1% level. However, one potential issue of the 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 column (2), the coefficient of access to electricity is positive and statistically significant at the 1% level, indicating electrification rate has a positive effect on financial development. Specifically, a 1% increase in access to electricity is associated with 0.29% rise in private sector credit to GDP ratio.

3.2 | 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 two-stage least square estimates are presented in Table 3. In column (1) of Table 3, we regress private sector credit to GDP ratio on only access to electricity, while other columns increasingly add more covariates concluding with column (9) that includes the full set of controls. The results from Table 3 show 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% level in all regressions) but also economically significant.

Trade openness, natural resources, and remittance are the other three variables that significantly affect financial development. Table 3 shows 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 Table 3 suggest that reserves of natural resources and remittances negatively affect the developments of financial sector. These findings are also in line with a large body of empirical works (e.g. Bhattacharyya & Hodler, 2014; Brown et al., 2013) that have found that resource wealth (so-called natural resource curse in finance) and migrant's remittances affect financial development negatively.

The first-stage regression outcome is also reported in Table 3. The coefficients of mean slope of terrain are highly statistically significant at the 1% level, with the anticipated sign. High level of terrain slope would likely make extensions of the electrical grid more challenging. Another critical identifying assumption is that the instrumental variable is uncorrelated with the second-stage regression errors, so that variations in average slope of terrain can be utilized as an exclusion restriction in the IV estimates. The Hansen test for over-identification restrictions indicate the validity of our instruments. Again, we follow the approach proposed by Altonji et al. (2005) by examining the sensitivity of the estimates to the inclusion and exclusion of control variables. The incremental addition of controls across columns (1) to (9) in Table 3 indicates that the IV estimates are not sensitive to the inclusion and exclusion of covariates hence, our controls are also relevant. Furthermore, as indicated by Goldsmith-Pinkham et al. (2020) and Borusyak et al. (2022), the variation in exposure of shares need not be exogenous but identifying assumptions can be plausible when the variations in the exogenous shocks can be shown to be exogenous in settings with many cross-sections. We therefore also test whether our instrument is valid following the approach by Borusyak et al. (2022). We report the '*effective*' *F*-statistics (Montiel-Pflueger *F*-statistics) based on the weak shift-share IV (SSIV) test. In almost all the estimations, the test rejects the null hypothesis of weak instrument with the *F*-statistics above the critical values at a 5% confidence level with a 5% worst case bias (tau = 5%). These results suggest that our instrument is sufficiently correlated with electrification rate to serve as a potentially good instrument. Moreover, the Anderson-Rubin test of weak instrument is rejected in all estimations.

3.3 | Robustness checks

In this section, we conduct four sets of sensitivity checks. First, we check the robustness of our baseline estimates to potential bias from omitted variables. Second, we estimate the baseline model with the IV strategy developed by Lewbel (2012). Third, we estimate our benchmark model by using the generalized method of moments (GMM) technique. Fourth, 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.

TABLE 3 Main IV results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)	(8)
ln (Access to electricity)	0.286***	0.342***	0.340***	0.466***	0.760***	0.898***	1.054***	0.735***	0.740***
	(0.050)	(0.061)	(0.059)	(0.098)	(0.192)	(0.232)	(0.413)	(0.226)	(0.211)
ln (Trade openness)		0.371***	0.354***	0.296***	0.304***	0.322***	0.413***	0.473***	0.365***
		(0.055)	(0.054)	(0.060)	(0.063)	(0.066)	(0.077)	(0.074)	(0.085)
ln (Consumer price index)			−0.159	−0.148	−0.101	−0.167	−0.089	−0.080	−0.095
			(0.100)	(0.107)	0.122	(0.117)	(0.156)	(0.129)	(0.140)
ln (School)				0.412**	0.558**	0.556**	0.444	0.154	0.069
				(0.210)	(0.241)	(0.246)	(0.316)	(0.252)	(0.219)
ln (Real GDP per capita)					−0.284***	−0.409***	−0.481***	−0.318**	−0.356***
					(0.110)	(0.133)	(0.188)	(0.129)	(0.132)
ln (Natural resources)						−0.281***	−0.310**	−0.293***	−0.218***
						(0.047)	(0.056)	(0.048)	(0.050)
FDI							−0.004	0.008	0.007
							(0.014)	(0.010)	(0.009)
Remittances								−0.014***	−0.010***
								(0.004)	(0.004)
Institutional quality									0.053*
									(0.029)
First stage regression									
Average slope terrain x Crisis (0)	−0.356*** (0.037)	−0.324*** (0.037)	−0.319*** (0.0379)	−0.240*** (0.033)	−0.111*** (0.025)	−0.111*** (0.025)	−0.086*** (0.028)	−0.126*** (0.027)	−0.124*** (0.028)
Average slope terrain x Crisis (1)	−0.344*** (0.046)	−0.353*** (0.044)	−0.352*** (0.045)	−0.280*** (0.040)	−0.155*** (0.04)	−0.139*** (0.035)	−0.116*** (0.036)	−0.225*** (0.042)	−0.233*** (0.040)
Anderson-Rubin Wald-test: *F*-stat	18.47***	19.71***	20.73***	13.22***	8,24***	10.56***	7.50***	5.17***	5.48***
Hansen Overid. Test *p*-value	0.14	0.26	0.23	0.31	0.55	0.20	0.36	0.50	0.70
Weak SSIV test (Effective *F*-stats)	30.29**	37.80**	32.99**	28.37**	11.34**	11.57**	4.67**	3.41	3.7
Adj. R^2	0.26	0.35	0.34	0.28	0.13	0.13	0.02	0.29	0.32
Obs.	312	290	290	290	290	290	290	290	290
No. of countries	27	26	26	26	26	26	26	26	26

Note: Robust standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. SSIV is shift-share IV.

3.3.1 | Oster's (2019) bound estimate

Our baseline and IV estimates consistently show that access to electricity positively impacts financial development. In our discussion of external instrument quality, we demonstrate that our instrument satisfies a set of validity tests and the exclusion restriction assumption is also plausible. We also show that our IV estimates are insensitive to the exclusion or inclusion of covariates. Nevertheless, one may still argue that there could be omitted factors that are not fully controlled for by the observed variables in $\boldsymbol{X}_{it}$ in Equation (1). To further test our exogeneity assumption, we adopt the Oster (2019) bound analysis.

The argument often made in the literature is that if a coefficient remains stable after adding observed controls, then the omitted variable bias must be limited. However, Oster (2019) highlights the value of R^2 should also be considered, because the coefficient may still be stable after adding uninformative controls. The Oster's (2019) method allows us to bound the omitted variable bias, therefore partially identify causality by comparing two regression equations: (i) a *controlled* regression such as Equation (1) which includes key variable of interest and observed covariates $\boldsymbol{X}_{it}$; and (ii) an *uncontrolled* regression that includes only the key variable of interest, and any observable controls whose correlation with the key explanatory variable is uninformative about selection bias.

To estimate the degree of bias in the estimate of β_1 in Equation (1) arising from the omitted unobservable factors, the method utilizes two pieces of information. First is the value of δ, that is, the relative degree of selection on observed and unobserved variables. Following Oster (2019), we set the value of δ equals to one. Second is the theoretical maximum R^2 (denoted as R^2_{max}) from a hypothetical regression that includes all observable and unobservable variables. Following the suggestions of Oster (2019), we set R^2_{max} equals to $\min\left\{1, 1.3\hat{R}^2\right\}$, where $\hat{R}^2$ can be obtained from the FE model. The identified set (or bounds) $\left[\hat{\beta}, \beta^*\left(R^2_{max}, \delta = 1\right)\right]$ is given by $\left[\hat{\beta}, \beta^*\left(\min\left\{1, 1.3\hat{R}^2\right\}, \delta = 1\right)\right]$ that contains the true estimate. The parameter β^* can be estimated as $\hat{\beta} - \left(\dot{\beta} - \hat{\beta}\right)\frac{R^2_{max} - \hat{R}^2}{\hat{R}^2 - \dot{R}^2}$, where $\dot{\beta}$ and $\dot{R}^2$ are from the FE regression without covariates, whereas $\hat{\beta}$ and $\hat{R}^2$ can be retrieved from the FE regression with covariates. The bound analysis results are easy to interpret. Based on Oster (2019), if the bounded set does not include zero, then the true effect of each treatment on the dependent variable is not zero. The estimation results of the baseline FE regression, therefore, are robust.

Table 4 presents the bounds of values for β from the FE model with full controls. For ease of comparison, column (1) reproduces the controlled-effect estimates in Table 2. The Oster's (2019) bound estimates are reported in column (2) of Table 4. It can be seen that the identified bounds of the estimate in column (1) do not include zero, indicating that our FE results are robust to the potential omitted variable bias. Moreover, looking at the magnitude of bound estimates, the estimated 0.29% rise in private sector credit to GDP ratio caused by 1% increase in access to electricity is robust, but the bound is slightly larger at 0.63%. Therefore, the Oster's (2019) bound estimate results confirm the positive effect of electrification rate on financial development, but of a marginally larger size than that presented in Table 2.

TABLE 4 Oster (2019) bound estimates.

	(1) Controlled effect $\hat{\beta}$ **(S.E.)**	**(2) Identified set** $\left[\hat{\beta}, \beta^*\left(\min\left\{1, 1.3\hat{R}^2\right\}, \delta = 1\right)\right]$
ln (Access to electricity)	0.292*** (0.081)	[0.292, 0.631]
Obs.	435	
$\hat{R}^2$	0.44	

Note: Robust standard errors in the parenthesis. *** denotes statistical significance at the 1% level.

3.3.2 | 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:

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

where ε_1 and ε_2 are the error terms; Y_1 stands for the dependent variable which is the private sector credit to GDP ratio 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 $E(\boldsymbol{XX}')$ 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 $\boldsymbol{Z} = \boldsymbol{X}$ 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 $(\boldsymbol{Z} - \overline{\boldsymbol{Z}})\hat{\varepsilon}_2$ as instruments, where $\overline{\boldsymbol{Z}}$ stands for the mean of $\boldsymbol{Z}$.

The Lewbel (2012) IV estimates are reported in Table 5. Column (1) presents the IV estimates results using the constructed instruments, while column (2) reports 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 10% level in all regressions, confirming the positive impact of electrification rate on financial development. The results of Table 5 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.

3.3.3 | System GMM estimation

We provide additional robustness check by following adding lag of the dependent variable (financial development) as financial development may persist and estimate our model with the GMM technique. As indicated by Roodman (2009), the system GMM approach uses the lag of the independent variables as instruments and internal transformations to help address endogeneity issues which are basically sources of unobserved heterogeneity, simultaneity, and dynamic endogeneity. Furthermore, we employ the collapsing method proposed by Holtz-Eakin et al. (1988) to limit the reduction in data points resulting from the use of the instruments. We also use the forward orthogonalization method of Arellano and Bover (1995) to limit the number of instruments. We report the AR (2) to test second-order serial correlations to check whether the deeper lags of the instruments are correlated with deeper lags of the disturbances. We also report the *p*-value of the Hansen test to test for over-identifying restrictions with valid over-identifying restrictions as the null hypothesis. The results are presented in Table 6. We find that the GMM estimates are consistent and efficient given that the AR (2) test and the Hansen test are both satisfied. Overall, the results are qualitatively similar to our 2SLS and Lewbel (2012) IV estimates, which confirms electrification rate has a positive influence on financial development.

TABLE 5 Access to electricity and financial development, Lewbel (2012) IV estimates.

	Generated IV	Generated and external IV
	(1)	(2)
	ln (Private sector credit/GDP)	ln (Private sector credit/GDP)
ln (Access to electricity)	0.245*	0.277**
	(0.135)	(0.129)
ln (Trade openness)	0.284***	0.286***
	(0.097)	(0.097)
ln (Consumer price index)	−0.241**	−0.247**
	(0.118)	(0.118)
ln (School)	−0.145	−0.122
	(0.191)	(0.189)
ln (Real GDP per capita)	−0.049	−0.071
	(0.090)	(0.085)
ln (Natural resources)	−0.233***	−0.238***
	(0.051)	(0.051)
FDI	0.026***	0.025***
	(0.008)	(0.008)
Remittances	−0.010*	−0.010**
	(0.005)	(0.005)
Institutional quality	0.036*	0.035*
	(0.021)	(0.021)
R^2	0.42	0.42
Obs.	290	290
No. of countries	26	26
Hansen *J* stat	31.93	32.60
Hansen *J* *p*-value	0.13	0.14

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

3.3.4 | Dividing sample into multiple time periods

We further examine the robustness of the results by splitting 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 two negative shocks that affect the financial sector development: 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 (2000–2006, 2013–2018) and crisis period (2007–2012). The regression results are reported in Table 7. 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 marginally larger in crisis period.

TABLE 6 Access to electricity and financial development, system GMM.

	Two-step system GMM
	ln (Private sector credit/GDP)
Lag 1 ln (Private sector credit/GDP)	0.895***
	(0.023)
ln (Access to electricity)	0.085***
	(0.026)
ln (Trade openness)	0.051*
	(0.0306)
ln (Consumer price index)	−0.044***
	(0.009)
ln (School)	0.078
	(0.068)
ln (Real GDP per capita)	−0.047*
	(0.026)
ln (Natural resources)	0.022
	(0.010)
FDI	0.020***
	(0.006)
Remittances	0.007***
	(0.001)
Institutional quality	0.023***
	(0.004)
AR (2)	0.146
Hansen Overid. *p*-value	0.463
Obs.	386
No. of instruments	33
No. of countries	36

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

4 | MECHANISMS

In this section, we examine whether mobile phone and bank branches diffusion 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 the 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

TABLE 7 FE regression (divide the sample into multiple periods).

	Non-crisis period	Crisis period
	(1)	(2)
	ln (Private sector credit/GDP)	ln (Private sector credit/GDP)
ln (Access to electricity)	0.300***	0.306*
	(0.099)	(0.157)
ln (Trade openness)	0.422***	−0.194
	(0.128)	(0.188)
ln (Consumer price index)	−0.105	−0.563
	(0.119)	(0.441)
ln (School)	0.276	0.127
	(0.181)	(0.555)
ln (Real GDP per capita)	0.296	0.814
	(0.281)	(0.610)
ln (Natural resources)	0.015	−0.040
	(0.034)	(0.053)
FDI	0.009	0.0005
	(0.013)	(0.004)
Remittances	−0.027**	−0.004
	(0.010)	(0.007)
Institutional quality	0.029	0.033
	(0.041)	(0.056)
Country FE	Yes	Yes
Year FE	Yes	Yes
R^2	0.49	0.44
Obs.	269	166
No. of countries	37	36

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

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 the same, banks are able to expand their credit hence can lead to the development of the financial sector.

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 8 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

TABLE 8 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.

TABLE 9 Effect of access to electricity and the potential channels on financial development.

	Private sector credit/GDP		
Dependent variable	(1)	(2)	(3)
Access to electricity	0.347***	0.252***	0.235***
	(0.049)	(0.047)	(0.047)
Mobile cellular subscriptions		0.128***	
		(0.016)	
Number of bank branches			0.466***
			(0.040)
Controls	Yes	Yes	Yes
Obs.	435	433	373
R^2	0.45	0.51	0.54

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

of mobile phone and number of bank branches. In particular, access to electricity is associated with a 0.66% and 0.25% 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 private sector credit to GDP ratio should decrease the scale of the coefficient on electrification rate or render it insignificant. Table 9 presents the results. Columns (2) and (3) 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.

5 | CONCLUSION AND POLICY RECOMMENDATIONS

This paper investigates the impact of access to electricity on financial development in Sub-Saharan Africa. To do so, we use the average slope of terrain 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 underpin 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 feedback into the public finances through taxes for reinvestment. Moreover, governments should take advantage of technological advances in off-grid solutions to strategically promote productive electricity uses, especially in rural areas. More importantly, policymakers need to recognize electrification as a necessary, long-term investment for economic transformation. Any plans that aim 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

A correlation matrix in Table A2 between the institutional quality index and the six variables is 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 A1 Principal component analysis of institutional quality.

Component	Eigen value	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

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) Government 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
Cameroon	CMR	Cote d'Ivoire	CIV
Congo, Rep.	COG	Congo, Dem.Rep.	COD
Cabo Verde	CPV	Comoros	COM
Ghana	GHA	Gabon	GAB
Gambia	GMB	Guinea	GIN
Liberia	LBR	Guinea-Bissau	GNB
Madagascar	MDG	Kenya	KEN
Mozambique	MOZ	Lesotho	LSO
Mauritius	MUS	Mali	MLI
Nambia	NAM	Mauritania	MRT
Nigeria	NGA	Malawi	MWI
Sudan	SDN	Niger	NER
Seychelles	SYC	Rwanda	RWA
Togo	TGO	Senegal	SEN
Uganda	UGA	Eswatini	SWZ
Zambia	ZMB	Tanzania	TZA
South Africa	ZAF	Zimbabwe	ZWE