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Governance, credit access and clean cooking technologies in Sub-Saharan Africa: Implications for energy transition

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Abstract

There is a global effort toward reducing or eliminating dirty fuels and technologies for cooking due to their severe health, environmental and economic implications. Reducing dirty energy usage requires an effective transition toward clean fuels and technologies for cooking. Effective governance and financial systems are needed to hasten the transition toward clean fuels and technologies for cooking. However, not much is known empirically about the role of access to credit and governance in the transition towards clean cooking technologies, especially in sub-Saharan Africa (SSA). This study, therefore, utilizes the two-step-dynamic system generalized method of moment estimator to investigate the effect of access to credit and governance on the adoption of clean cooking technologies in SSA. The findings indicate that access to credit and governance variables do not facilitate clean cooking technologies usage. The conditional analysis also reveals that the governance variables moderate the effect of access to credit to impede the adoption of clean fuels and technologies for cooking. The findings indicate that economic growth, education, and rural population drive the adoption of clean cooking technologies. Sensitivity checks show that the effect of access to credit and governance on clean fuels and cooking technologies usage differs among income and regional groups within SSA. We, therefore, argue that better financial and governance systems are required to hasten the transition toward clean fuels and technologies for cooking in SSA.

JEL Classification: P48; Q48

Keywords: Governance; Access to credit; Clean cooking technologies; Sustainable Energy for All; Affordable and clean energy; Sub-Saharan Africa

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1. Introduction

This study investigates the role of access to credit and governance in the transition towards clean fuels and technologies for cooking in Sub-Saharan Africa (SSA). Sustainable development goal 7 (SDG 7) requires countries to ensure access to affordable, reliable, sustainable, and modern energy for all. Despite attempts to provide access to modern and clean energy, most of the world's population still relies on traditional polluting fuels and technologies for cooking. The Energy Sector Management Assistance Program, hereafter ESMAP (2020) report suggests that approximately 2.8 million people still rely on traditional environmentally unfriendly fuels and cooking technologies. The overreliance on conventional polluting fuels and technologies for cooking poses severe economic, health, and environmental problems. For instance, available data shows that cooking with traditional polluting fuels and technologies has resulted in approximately four (4) million deaths due to indoor pollution[1] and has further costs the global economy more than 2.4 trillion dollars per annum. Again, the health cost and the cost to women using dirty cooking fuels and technologies are estimated to be \$1.4 trillion and \$0.8 trillion, respectively (ESMAP, 2020).

The severe economic, health, and environmental cost associated with using traditional polluting fuels and technologies calls for policymakers to prioritize policies and strategies for quickening the transition towards adopting clean fuels and cooking technologies. While policymakers have been keen on promoting the adoption of clean cooking technologies (Bono & Giacomarra, 2016), the current progress report on SDG 7 has slackened (ESMAP, 2020). For instance, approximately four (4) billion people worldwide still lack access to clean, efficient, convenient, safe, reliable, and affordable cooking energy (ESMAP, 2020). As shown in Fig. 1, regional analysis suggests that access to clean cooking technologies and fuels differs among geographical regions. From Fig. 1, North America has made significant progress in achieving universal access to clean cooking fuels and technologies, with 100 % of the population having access to clean fuels and technologies for cooking. Also, in Europe & Central Asia and, the Middle East & North Africa, over 90 % of its population has access to clean fuels and technologies for cooking. Latin America & the Caribbean and East Asia & Pacific have also made significant progress, with more than 80 % of Latin America & Caribbean and 60 % of the East Asia & Pacific population having access to clean fuels and technologies for cooking. Evidence, as presented in Fig. 1, shows that South Asia and SSA countries have less access to clean fuels and technologies for cooking; however, South Asia has significantly improved, with approximately 50 % of its population with access to clean fuels and technologies for cooking.

Despite significant progress in increasing access to clean fuels and technologies for cooking in other regions, SSA progress has been abysmal. As displayed in Fig. 1, less than 20 % of the SSA population has access to clean fuels and technologies for cooking. In other words, SSA is off track in achieving universal access to modern and clean cooking fuels and technologies by 2030. Recently, policymakers and researchers have attributed the slow adoption of clean fuels and technologies for cooking in SSA to rural-urban divides, poor-infrastructure facilities, high monetary costs, lack of awareness of the benefits of using clean cooking fuels and technologies, and cultural barriers (Ekouevi, 2013; Schlag & Zuzarte, 2008). While these identified factors are critical, we argue that fundamental factors such as governance and credit accessibility should be given the uttermost attention since some of these already identified barriers can be overcome

[1] https://www.borgenmagazine.com/clean-cooking/.

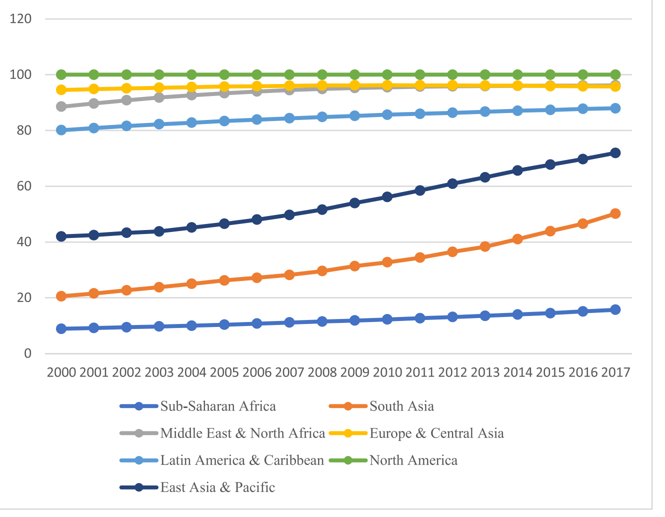

Fig. 1. Access to clean fuels and technologies for cooking (% of population).
Source: Author's construct based on World Bank world development indicators database.

with good governance and financial systems. Therefore, to improve the adoption of modern and clean cooking technologies in SSA, it calls for policymakers to prioritize governance and credit accessibility in the design and implementation of national energy policies that intend to promote universal access to modern and clean cooking fuels and technologies by 2030.

Effective governance systems can promote the development and adoption of clean fuels and technologies for cooking by shaping energy policies. Effective governance can create a vision for the energy sector and provide the enabling environment needed to develop a market for clean cooking technologies. In other words, the effectiveness of energy policies for hastening the transition towards clean fuel and technologies for cooking depends on governance. Therefore, weak governance systems can render energy policies ineffective and impede the development and use of clean cooking fuels and technologies and vice versa. Also, a sound governance system can quicken the transition towards clean cooking fuels and technologies by eliminating or reducing coordination failure. The slow development and usage of clean fuels and technologies for cooking could be attributed to poor coordination around the common strategic approach for developing clean cookstoves and fuel markets (Cookstove, 2011). Therefore, a governance system that promotes effective coordination among actors such as governments, cooking technologies manufacturers, consumers, and non-governmental organizations would provide opportunities to achieve the economies of scale associated with producing clean cooking technologies (Cookstove, 2011). Also, a governance system that enforces the rule of law and further ensures the protection of individual property rights can lead to the development and adoption of clean cooking technologies. Boosting the development of clean cooking technologies through enforcement of contracts can result in massive production and supply of clean cooking technologies, driving the price of these technologies downwards.

Also, a developed financial system that easily provides access to credit to households and clean cooking technologies manufacturers is vital for a successful transition towards clean cooking fuel and technologies. Cookstove (2011) indicated that households having access to credit through microfinancing could enable households an opportunity to overcome the higher initial upfront cost of clean fuels and technologies and thus improve households' usage of clean cooking technologies. Credit accessibility can further improve the adoption of clean cooking technologies by enhancing a household's income. The provision of credit to households could enable them to create microenterprises, reduce poverty and increase capital accumulation, thereby improving their incomes (Twumasi, Jiang, Ameyaw, Danquah, & Acheampong, 2020). Improving households' income through access to credit could enable patronizing clean cooking technologies. In addition, clean cooking technologies manufacturers and distributors having access to credit could allow them to expand investment and production of clean technologies for cooking. Expanding investment and production of clean technologies for cooking could reduce the price of these technologies, thereby increasing household demand and usage (Cookstove, 2011). Similarly, a developed financial system could easily mobilize and channel household savings through credit to the new commercial entrants to the clean cooking technologies market, which can significantly facilitate their ability to expand the production and supply of clean cooking technologies.

From the discussion, it is indisputable that governance and access to credit play a significant role in the adoption of clean cooking technologies. The existing literature has deployed household survey data to examine the determinants such as household income, product price, household wealth, education, and cultural factors on the adoption of clean cooking technologies (See, for instance, Beyene & Koch, 2013; Gould, Urpelainen, & Hopkins Sais, 2020; Guta, 2020; Nuño Martínez, Mäusezahl, & Hartinger, 2020; Twumasi et al., 2020). However, not much is known empirically about the contributions of governance and access to credit in adopting clean cooking technologies in SSA at the macro-level.

Therefore, this study examines the effect of access to credit and governance on adopting clean cooking fuels and technologies in SSA. Using SSA for this study will contribute significantly to literature and policy discussions on accelerating the adoption of clean cooking technologies in the continent. This is because it is the region with the least access to clean fuels and technologies for cooking and has a weak financial system globally (Acheampong, 2019; Ibrahim & Alagidede, 2018). Mlachila, Jidoud, Newiak, Radzewicz-Bak, and Takebe (2016) show that despite improvement in financial development in SSA, both financial markets and financial institutions are less developed than in other developing regions. These authors indicated that credit to private sectors as a ratio of Gross Domestic Product (GDP) in SSA has risen by approximately 10 % points since 1995, to about 21 % in 2014; however, it remains only about half the size of that in the Middle East and North Africa, East Asia, and Latin America and the Caribbean. SSA also has a weak governance system characterized by corruption, political instability, poor accountability and regulation, and the rule of law (Acheampong, Dzator, & Savage, 2021; Gossel, 2018). From a policy perspective, SSA is at the forefront of implementing the Sustainable Energy for All (SEE4ALL) goal; however, the status of its financial and governance systems raises a critical question about their role in achieving the SEE4ALL goal. Therefore, the critical question of policy concern is, "*what are the roles of governance and access to credit in achieving universal access to affordable, reliable, modern, and clean technologies for cooking in SSA by 2030?*" To answer this broad question, this study seeks to address the following specific research questions.

1. *What is the effect of access to credit on the adoption of clean cooking technologies in SSA?*
2. *Does governance promote the adoption of clean cooking technologies in SSA?*
3. *Does the effect of access to credit on the adoption of clean cooking technologies conditioned by governance in SSA?*

4. *Do the difference in governance and credit accessibility account for variations in the adoption of clean cooking technologies among SSA's sub-regions and income groups?*

In answering the research question, this paper contributes to knowledge and policy in the following ways: From a policy perspective, understanding the impact of access to credit and governance on the adoption of clean cooking technologies in SSA is essential to support any policy decision to accelerate the adoption of modern and clean cooking technologies in the region. For instance, The African Energy Commission has developed the Africa Energy Transition Program to enhance access to affordable clean energy for productive uses and households in Africa. This program is driven by Africa Union Agenda 2063, Sustainable Development Goals (SDGs), and Paris Agreement on climate change. Therefore, the outcome of this study will inform and support the policies and strategies for achieving the energy transition goal in the region. Besides, earlier studies have examined the contribution of the institutional environment in achieving energy efficiency (See, for instance, Acheampong et al., 2021; Amuakwa-Mensah, Klege, Adom, Amoah, & Hagan, 2018). Our study augments the existing body of knowledge by providing new empirical evidence on the contribution of fundamental variables such as access to credit and governance to the transition towards clean fuels and cooking technologies in SSA, which has not received much empirical attention in the existing literature. Additionally, our study contributes to knowledge by examining how governance conditions the effect of access to credit on the adoption of clean fuels and cooking technologies and further explores how the difference in governance and financial development among regions and income groups affect the accessibility to clean fuels and cooking technologies.

2. Brief literature review

The majority of the literature on the adoption of clean cooking technologies such as Liquefied Petroleum Gas (LPG), clean cooking stoves, etc. are micro-studies (See, for instance, Beyene & Koch, 2013; Gould et al., 2020; Guta, 2020; Nuño Martínez et al., 2020; Shari, Dioha, Abraham-Dukuma, Sobanke, & Emodi, 2022; Twumasi et al., 2020). These studies have explored how economic, socio-demographic, fuel availability and behavioral and environmental variables affect the adoption of clean cooking technologies. For instance, Beyene and Koch (2013) investigated the factors affecting the adoption of cooking technologies (Mirte and Lakech cook stoves) in urban Ethiopia. The study revealed that the product's price, household income, and wealth drive the adoption of Mirte and Lakech cookstoves; however, the availability of alternative technologies impedes their adoption. In another study, Guta (2020), using data from 195 households, indicated that household income, household size, number of household cattle, education and off-farm income, and monetary incentives increase the probability of adopting energy-efficient and renewable energy technologies. Using large-scale household data from two Indian states (Kerala and Rajasthan), Gould et al. (2020) found that education and perceptions that LPG is reasonable and affordable and progressive health-related perceptions are positively related to LPG ownership.

Also, Amoah (2019), using household data from Ghana, revealed that the educational level of household head, income, the convenience of energy, distance to energy sources, and the effect of energy source affect the choice of using either modern cooking fuels or traditional cooking fuels. In Afghanistan, Paudel, Khatri, and Pant (2018) revealed that residence in urban areas, availability of electricity, higher household wealth, high education, married status, and different cooking place increase the adoption of LPG relative to traditional fuels. However, the study indicated that large family sizes and aged household heads increase the likelihood of using animal dung as cooking fuel. While the prior studies failed to acknowledge the importance of cultural variables in the adoption of clean cooking technologies, Nuño Martínez et al. (2020), using household data from Andean, found that LPG price; technologies not matching local cooking needs; difficulties completing other daily chores while cooking; the need to save time; and the perception that LPG affects the taste of food impede the adoption of LPG.

At the macro level, different studies have examined the impact of governance and access to credit on energy poverty (access to electricity). For instance, Acheampong, Shahbaz, Dzator, and Jiao (2022), using data from 43 SSA countries, indicated that governance has an insignificant effect on access to electricity; however, governance moderates income inequality and economic growth to impede access to electricity. Similarly, Sarkodie and Adams (2020), focusing on 35 SSA countries, revealed that governance exerts a significant positive effect on access to electricity. Onyeji (2010) also identified that gross domestic savings, which form bulks of resources to finance energy projects and institutional quality, drive access to electricity in developing countries. Using Bayesian Model Averaging, Zhang, Shi, Zhang, and Xiao (2019) noted that access to finance (credit) is one of the most influential variables that affect access to electricity in the long run.

A critical review of the available literature suggests that the existing studies have mainly examined the role of household characteristics variables such as household income, household wealth, education, household size, and among others, on the usage or adoption of clean cooking technologies such as LPG, clean cooking stoves, etc. In addition, some emerging studies on energy poverty at the macro-level have explored the role of governance and access to finance on access to electricity and not clean fuels and cooking technologies. Thus, there is a lack of empirical study at the macro-level that has examined the role of access to credit (finance) and governance in the adoption of clean cooking fuels and technologies in developing countries, especially SSA, which is the most energy-poorest region. This study fills the knowledge gap and contributes to policy discussion by investigating the contributions of access to credit and governance on adopting clean cooking technologies in SSA.

3. Methodology and data

3.1. Specification of the empirical model

In this study, we adopt the dynamic reduced-form equation to estimate the impact of access to credit and governance on the adoption of clean cooking technologies in SSA, specified in Eq. (1). From Eq. (1), the adoption of clean cooking technologies is explained by the past adoption of clean cooking technologies, access to credit, governance variables, and other control covariates.

$$\ln CCT_{i,t} = \alpha_0 \ln CCT_{i,t-1} + \beta_1 \ln Credit_{i,t} + \beta_2 WGI_{i,t} + \delta_j \ln X_{i,t} + \varepsilon_{it} \tag{1}$$

In this study, we hypothesize that governance moderates the effect of access to credit on the adoption of clean cooking technologies in SSA. This hypothesis emerges from the evidence that governance systems capable of enforcing loan contracts prevent people from defaulting and, thus, increase the confidence of lenders in borrowers and further increase access to credit. In addition, Law and Azman-Saini (2012) argue that information asymmetry, adverse selection, and moral hazards could limit the financial system's role in mobilizing and channeling borrowers' savings. However, effective governance systems that can address these market failure challenges through effective legal systems and adequate enforcement of contracts would improve access to credit (Law & Azman-Saini, 2012; Nam, Bon Sesay, Wynne, & Zhang, 2020). Therefore, as governance plays an essential role in financial development in enhancing access to credit, we argue that the impact of access to credit on the adoption of clean cooking technologies could be moderated by governance. Therefore, Eq. (2) is used to examine the interactive effect of governance and access to credit on the adoption of clean cooking technologies in SSA.

$$\ln CCT_{i,t} = \alpha_0 \ln CCT_{i,t-1} + \beta_1 \ln Credit_{i,t} + \beta_2 WGI_{i,t} + \beta_3 (WGI \times \ln Credit)_{i,t} + \delta_j \ln X_{i,t} + \varepsilon_{it} \quad (2)$$

Where $i = 1 — N;\ t = 2000 — 2017$. $lnCCT_{i,t}$ is the adoption of clean cooking technologies in country i at year t. $lnCCT_{i,t-1}$ is lagged adoption of clean cooking technologies of country i at year t; $\ln Credit_{it}$ is credit accessibility in country i at year t; $\beta_2 WGI_{i,t}$ is governance variables of country i at year t; $(WGI \times \ln Credit)_{i,t}$ is the measure of interaction between governance variables and credit accessibility in country i at year t; $\ln \boldsymbol{X}_{i,t}$ is a vector of control covariates such as economic growth, urban population, rural population, and education that potentially affect the adoption of clean cooking technologies. ε_{it} is the unobserved error term. a_0 the coefficient on the lagged adoption of clean cooking technologies; $\beta_1 - \beta_3$ are coefficients to be estimated while $\delta_j$is the coefficient of the set of the control variables to be estimated.

3.2. Estimation strategy

This paper applied the Blundell and Bond (1998) two-step dynamic system-generalized method of moment to estimate the above-specified equations. In the presence of unobserved country and time fixed effect in the above equations, Arellano and Bond (1991) argue that estimating such equations with a conventional econometric technique such as OLS could lead to biased results since the lag of the independent variable correlated with the unobserved effects. The above-specified equations are differenced to eliminate the unobserved country and time effects to present unbiased estimates. Therefore, Arellano and Bond (1991) developed the first difference generalized method of moment (GMM) estimators that use the first differencing transformation to remove these unobserved country and time effects. However, in a simulation study, Blundell and Bond (1998, p. 115) argue that the Arellano and Bond (1991) first difference GMM estimator has poor precision and large finite sample bias, especially when the time series observation is small, and the autoregressive parameter is relatively large. Therefore, Blundell and Bond (1998) developed the system-generalized method of moment (System-GMM) to address the weakness of the first difference GMM. Blundell and Bond (1998) system-GMM uses the lagged differences of the dependent variable as instruments for equations in levels and includes the lagged levels of the dependent variable as instruments for equations in the first differences. Comparatively, the system-GMM estimator generates good instruments that are good predictors for endogenous variables and thus performs better than the first difference GMM even when the variables are persistent. To present consistent results, the Hansen test is used to check for the validity of the instruments. Additionally, this study also tests for the first and second-order autocorrelation.

3.3. Data

This study uses panel data for 43 SSA[2] from 2000 to 2017 to examine the effect of access to credit and governance on the adoption of clean fuels and cooking technologies. In this study, we follow the International Energy Agency (hereafter, IEA) (International Energy Agency, 2020) to define the adoption of clean fuels and cooking technologies as a household having access to (and making primary use of) modern fuels and technologies, including natural gas, liquefied petroleum gas (LPG), electricity, ethanol, and biogas, or intermediate and advanced improved biomass cookstoves (ISO tier ≥ 1). Therefore, the adoption of clean cooking technologies is measured using the percentage of people with access to modern and clean cooking fuels and technologies.

Domestic credit provided by the financial sector (% of GDP) is used as a proxy for access to credit. Also, the rule of law, government effectiveness, control of corruption, regulatory quality, voice and accountability, and political stability denote governance. In addition to using the individual governance indicators, we applied the principal component analysis to these six individual governance indices to generate a composite governance indicator. The six aggregate indicators of governance used in this study are in their standard normal units, ranging from approximately −2.5 to 2.5, with higher values corresponding to better outcomes (Kaufmann et al., 2011). For the control variables, education is represented using gross secondary school enrollment. GDP per capita (constant 2010 US$) is used as an indicator of economic growth. Urban population is represented with the total urban population, while the rural population is represented using the total rural population. For estimation, we transformed the clean fuels and cooking technologies, economic growth, rural population, urban population, and access to credit, while the governance variables remained untransformed. The governance indicators were sourced from the World Governance Indicators (WGI) database, while the remaining variables were obtained from the World Development Indicators (WDI) database.

The descriptive statistics for the variables are presented in Table 1, while the correlation among the variables is shown in Table 2. From Table 2, it can be observed that the correlation coefficients among the independent variables are relatively small. However, the correlation among the governance indicators is relatively high, and therefore, these indicators were estimated in different models.

4. Results and discussion

Table 3 presents the estimates without including income and regional dummy variables in the models. In Table 3, the estimates indicate that lagged clean cooking technologies usage significantly positively affects contemporaneous adoption of clean cooking technologies. The policy implication is that adopting clean cooking technologies in the past substantially contributes to the current adoption of clean cooking technologies. It is indicated that using clean cooking technologies has a lot of benefits, such as lower emissions, efficiency, and quality, and improved health conditions relative to dirty cooking fuels (Ackah, Bukari, Banye, & Bobio, 2021; Gould et al., 2020). Therefore, previous users of clean cooking technologies realizing

[2] Angola; Benin; Botswana; Burkina Faso; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo, Dem. Rep.; Congo, Rep.; Cote d′Ivoire; Eswatini; Ethiopia; Gambia, The; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mauritius; Mozambique; Namibia; Niger; Nigeria; Rwanda; Sao Tome and Principe; Senegal; Seychelles; Sierra Leone; South Africa; Sudan; Tanzania; Togo; Uganda; Zambia; Zimbabwe.

Table 1
Descriptive statistics.

Variable	Definitions	Mean	Std. Dev.	Min	Max	Sources
lnclean	Clean fuels and cooking technologies	1.813	1.656	-1.897	4.536	WDI
lnrgdpc	Economic growth	6.945	0.964	5.267	9.557	WDI
lnsse	Education	3.599	0.593	1.810	4.632	WDI
lnrural	Rural population	15.345	1.699	10.598	18.380	WDI
lnurban	Urban population	14.781	1.533	10.619	18.364	WDI
lndcpf	Access to credit	2.814	1.435	-5.942	5.261	WDI
WGI	Composite governance index	-0.643	0.602	-2.341	1.211	Author's computation
CC	Control of corruption	-0.589	0.614	-1.562	1.217	WGI
GE	Government effectiveness	-0.708	0.599	-1.884	1.049	WGI
PV	Political stability	-0.516	0.899	-2.699	1.282	WGI
RQ	Regulatory quality	-0.628	0.570	-2.236	1.127	WGI
RL	Rule of Law	-0.654	0.630	-2.009	1.077	WGI
VA	Voice and accountability	-0.496	0.694	-1.830	0.986	WGI

Table 2
Correlation matrix.

Variables	lnclean	lnrgdpc	lnsse	lnrural	lnurban	lndcpf	WGI	CC	GE	PV	RQ	RL	VA
lnclean	1												
lnrgdpc	0.8354	1											
lnsse	0.64	0.7396	1										
lnrural	-0.4851	-0.4916	-0.4228	1									
lnurban	-0.2665	-0.2716	-0.2036	0.9194	1								
lndcpf	0.1708	0.2971	0.2248	0.1892	0.1977	1							
WGI	0.4007	0.4782	0.4221	-0.1921	-0.1168	0.337	1						
CC	0.4842	0.5278	0.4928	-0.5471	-0.4679	0.2099	0.7654	1					
GE	0.5456	0.6093	0.4881	-0.355	-0.2646	0.3462	0.8719	0.8615	1				
PV	0.425	0.4288	0.3774	-0.6065	-0.5196	0.0741	0.6664	0.7577	0.7163	1			
RQ	0.4007	0.4782	0.4221	-0.1921	-0.1168	0.337	1	0.7654	0.8719	0.6664	1		
RL	0.4943	0.5282	0.4962	-0.4372	-0.366	0.3091	0.8548	0.8905	0.9017	0.8046	0.8548	1	
VA	0.4058	0.4176	0.4387	-0.3673	-0.2121	0.1705	0.7337	0.7189	0.7405	0.7315	0.7337	0.8209	1

these benefits may spread this information to non-users and, thus, encourage non-users to use the technology. A recent study by Shari et al. (2022) has confirmed that information sharing through "word of mouth" about the benefits of clean cooking technologies (clean cookstoves) usage speed up the adoption of these technologies.

The results show that the coefficient of economic growth is positive and significantly significant, confirming the energy ladder theory. The energy ladder theory suggests that as income increases, households switch from consuming dirty energy fuels such as biomass (firewood), charcoal, and kerosene to modern and clean fuels and cooking technologies such as LPG, electricity, and natural gas (Barnes & Floor, 1999). From a macroeconomy point of view, this theory suggests that transitioning toward clean fuels and technologies for cooking would improve as the economy grow. From a policy perspective, boosting economic growth is essential for accelerating the adoption of clean fuels and cooking technologies in SSA. Therefore, energy

Table 3
Governance, access to credit, and clean cooking technologies in SSA.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
L.lnclean	0.903***	0.929***	0.926***	0.945***	0.960***	0.926***	0.934***	0.937***
	(0.011)	(0.011)	(0.015)	(0.012)	(0.020)	(0.010)	(0.015)	(0.015)
lnrgdpc	0.168***	0.153***	0.139***	0.138***	0.077**	0.168***	0.129***	0.101***
	(0.018)	(0.019)	(0.032)	(0.023)	(0.032)	(0.014)	(0.029)	(0.019)
lndcpf	-0.039***	-0.021***	-0.030***	-0.023***	-0.022***	-0.026***	-0.018***	-0.005**
	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
lnsse	0.014	0.011	0.037***	-0.005	0.016	0.021**	0.030***	-0.010
	(0.012)	(0.009)	(0.006)	(0.010)	(0.012)	(0.009)	(0.009)	(0.008)
lnrural	0.039***	0.029	0.038*	0.034*	0.007	0.051***	0.024	-0.048***
	(0.013)	(0.018)	(0.021)	(0.019)	(0.015)	(0.017)	(0.016)	(0.012)
lnurban	-0.011	0.002	-0.031	-0.016	-0.003	-0.018	-0.011	0.066***
	(0.012)	(0.017)	(0.020)	(0.017)	(0.015)	(0.017)	(0.013)	(0.013)
WGI		-0.084***						
		(0.009)						
CC			-0.076***					
			(0.016)					
GE				-0.064***				
				(0.011)				
PV					-0.036***			
					(0.009)			
RQ						-0.084***		
						(0.007)		
RL							-0.101***	
							(0.013)	
VA								-0.073***
								(0.008)
Constant	-1.339***	-1.411***	-1.007***	-1.069***	-0.507**	-1.562***	-1.074***	-0.773***
	(0.166)	(0.161)	(0.231)	(0.197)	(0.225)	(0.124)	(0.246)	(0.155)
Observations	420	393	393	393	393	393	393	393
Hansen	38.684	29.909	28.607	27.327	24.647	33.294	27.377	31.710
Hansen p-value	0.829	0.994	0.997	0.998	1.000	0.980	0.998	0.988
AR (1)	0.012	0.006	0.018	0.009	0.004	0.009	0.012	0.008
AR (2)	0.878	0.510	0.586	0.627	0.344	0.561	0.620	0.370

Standard errors in parentheses. Hansen-test refers to the over-identification test for the restrictions in the dynamic system-GMM estimation. The AR (1) and AR (2) tests are the Arellano–Bond tests for the first and second-order autocorrelation in first differences. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

transitioning policies in SSA would fall short of their objectives in the face of poor and weak economic growth. This finding adds to the existing micro-studies such as Amoah (2019), Beyene and Koch (2013), and Gould et al. (2020), which revealed that household income increases the probability of using clean fuels and cooking technologies such as LPG.

The findings also show that the rural population has a statistically significant positive effect on clean cooking technologies usage. In contrast, the urban population has an insignificant (mainly) effect on clean cooking technology usage. The positive impact of the rural population on adopting clean cooking technologies could reflect the agenda of raising awareness about the advantages of using clean cooking technologies among rural folks. Also, some initiatives by international organizations such as the Global Alliance for Clean Cookstoves and national governments to scale up the usage of clean cooking technologies, such as cookstove programs in rural communities, could explain this result. Empirically, this result is consistent with Shari et al. (2022) simulation analysis, which revealed that there is growth in the adoption of clean cooking technologies among rural households because of the increase in their income.

Also, the estimates show that education has a positive and statistically significant effect on clean cooking technologies usage. This result indicates that improving human capital development in the form of education is critical for increasing the adoption of clean cooking technologies in SSA. Formal education enlightens people about the benefits of using clean cooking fuels and technologies relative to traditional cooking fuels such as biomass, charcoal, and kerosine. Existing evidence suggests that highly formal educated people use clean cooking fuel and technologies compared to people without or with low formal education (See, for instance, Guta, 2020). Generally, this finding confirms the existing literature suggesting that education improves the adoption of clean cooking technologies (Amoah, 2019; Beyene & Koch, 2013; Guta, 2020; Twumasi et al., 2020).

Further, the estimates show that access to credit has a statistically significant negative effect on the adoption of clean cooking technologies. This result manifests the weak and undeveloped financial system in SSA. SSA's financial system is characterized by generally low financial depth, access, and efficiency relative to other developing countries (Acheampong, 2019; Pelletier & Stijns, 2016). The development of clean cooking technologies requires finance. In a developed financial economy, clean cooking technologies manufacturers, retailers, and consumers can easily access finance at a minimal cost. However, SSA's weak financial system in SSA is eroding the benefits that consumers, retailers, and producers of clean cooking technologies could enjoy, therefore, slowing or impeding the adoption of the technologies in the region.

In addition, the results indicate that the composite governance index and specific governance variables such as control of corruption, government effectiveness, political stability, regulatory quality, the rule of law, and government accountability significantly negatively affect clean cooking technology usage. These results imply that governance has slowed or impeded the adoption of clean cooking fuels and technologies in SSA. This finding is not surprising since SSA has been characterized by a weak governance system in the form of poor contract enforcement and protection of property rights, corruption, poor accountability, an unstable political environment, and a weak regulatory framework (Acheampong et al., 2021). The aim of making 100 % of SSA's population use clean cooking fuels and technologies by 2030 hinges on the effectiveness of their governance system. Several energy projects in SSA have failed because of poor governance. For instance, Ikejemba, Mpuan, Schuur, and Van Hillegersberg (2017) analyzed the causes of the failure of 29 renewable energy projects in ten SSA countries,[3] and one of the fundamental causes behind the failure of these projects is weak governance. Ineffective governance can deter private investors from investing in clean cooking technologies and disrupt the market. Therefore, an effective governance system is needed to safeguard the sustainable clean fuels and technologies for cooking business in SSA and render clean cooking technologies programs and initiatives viable. This result further adds to Acheampong et al. (2022) findings that SSA's governance system has been ineffective in reducing energy poverty.

In Table 4, we include the regional and income dummy variables in the models to take care of regional and income-specific effects.[4] In Table 4, Models 1–6 suggest that Eastern-SSA

[3] These countries are Nigeria, Ghana, Kenya, Gabon, South Africa, Tanzania, Ethiopia, Mozambique, Malawi, and Uganda.

[4] For the income groups, the low-income group is used for the benchmark, while the West-SSA sub-region is used for the regional benchmark.

and Central-SSA countries have less clean cooking technology than Western-SSA. However, the results show that Southern-SSA countries have more clean cooking technology than Western-SSA countries. These estimates indicate that Southern Africa (including South Africa) is the sub-region with the highest access or usage of clean cooking technologies. In contrast, Central Africa has the least access to clean cooking technologies. According to the World Energy Outlook (2021), Southern African countries have 16 % access to clean cooking technologies (excluding South Africa, with 87 % of the population having access to clean cooking technologies), while 10 % of the Central Africa population has access to clean cooking technologies in 2020. Also, in 2020, Eastern and Western African countries will have 14 % access to clean cooking technologies. Table 4 also shows that clean cooking technologies usage is higher in lower-middle (LMIC), upper-middle (UMIC), and high-income (HIC)[5] countries than in low-income countries. This result is intuitive and further confirms the energy ladder theory because the less advanced countries rely heavily on traditional fuels such as biomass while more developed countries rely more on clean cooking technologies such as LPG.

Models 1–7 of Table 4 showed no change in the signs and significance levels of the variables after including regional-specific dummies in the models. However, From Models 8 to 14 of Table 4, with the inclusion of income dummies, except for the access to credit variable, there was no change in the signs of the remaining variables. It is observed from Models 8–14 that the sign-on access to credit coefficients changes to favorable after the inclusion of the income dummy variables. This finding indicates that differences in economic development among countries could condition access to finance or credit to have a disparity effect on the adoption of clean cooking technologies in SSA.

4.1. Does governance condition access to credit to affect clean cooking technologies usage in SSA?

We test if the effect of access to credit on the adoption of clean cooking technologies in SSA is conditioned by governance, and the estimates are presented in Table 5. From Table 5, the results indicate that the composite governance index and specific governance variables such as control of corruption, government effectiveness, political stability, regulatory quality, the rule of law, and government accountability moderate the effect of access to credit to reduce clean cooking technology usage in SSA significantly. Thus, in the presence of governance, credit access significantly impedes the adoption of clean cooking technologies in SSA. The existence of weak governance in SSA inhibits its financial development and limits access to credit by investors and households. A poor financial system due to weak governance impedes the development and adoption of clean cooking technologies in SSA. Therefore, improving governance to protect minority shareholders' interests and strengthening judicial independence and investor protection are essential for boosting financial development (Mlachila et al., 2016) and accelerating the adoption of clean cooking technologies in SSA.

[5] Seychelles is the only high-income country among the study sample; therefore, any interpretation of high-income countries should be referred to as Seychelles.

Table 4
Governance, access to credit, and clean cooking technologies in considering regional and income heterogeneities.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
L.lnclean	0.848***	0.913***	0.846***	0.878***	0.848***	0.894***	0.924***	0.893***	0.911***	0.895***	0.901***	0.893***	0.879***	0.874***
	(0.025)	(0.023)	(0.024)	(0.026)	(0.025)	(0.021)	(0.034)	(0.014)	(0.019)	(0.011)	(0.013)	(0.014)	(0.013)	(0.013)
lnrgdpc	0.195***	0.126***	0.131***	0.101**	0.195***	0.117***	0.090**	0.046	0.049***	0.026	-0.049**	0.046	0.034**	-0.044*
	(0.032)	(0.044)	(0.039)	(0.043)	(0.032)	(0.029)	(0.037)	(0.030)	(0.019)	(0.024)	(0.020)	(0.030)	(0.017)	(0.024)
lndcpf	-0.039***	-0.038***	-0.017***	-0.033***	-0.039***	-0.026***	-0.012***	0.009***	0.009*	0.019***	0.035***	0.009***	0.019***	0.040***
	(0.003)	(0.005)	(0.004)	(0.002)	(0.003)	(0.002)	(0.004)	(0.002)	(0.005)	(0.004)	(0.004)	(0.002)	(0.004)	(0.004)
lnsse	0.079***	0.085***	0.102***	0.095***	0.079***	0.085***	0.059**	0.072***	0.058***	0.060***	0.099***	0.072***	0.084***	0.107***
	(0.014)	(0.013)	(0.016)	(0.012)	(0.014)	(0.017)	(0.024)	(0.018)	(0.020)	(0.018)	(0.017)	(0.018)	(0.011)	(0.018)
lnrural	0.049**	0.048	0.016	-0.004	0.048**	0.047**	0.012	0.026	0.004	0.037***	0.033*	0.026	0.017	-0.003
	(0.021)	(0.034)	(0.034)	(0.036)	(0.021)	(0.024)	(0.030)	(0.028)	(0.018)	(0.013)	(0.019)	(0.028)	(0.023)	(0.015)
lnurban	-0.058***	-0.090***	-0.033	-0.017	-0.058***	-0.071***	-0.031	-0.036	-0.035**	-0.050***	-0.064***	-0.036	-0.045*	-0.028
	(0.021)	(0.030)	(0.038)	(0.034)	(0.021)	(0.027)	(0.034)	(0.025)	(0.017)	(0.016)	(0.020)	(0.025)	(0.025)	(0.018)
Eastern-SSA	-0.073***	-0.133***	-0.080*	-0.112***	-0.073***	-0.127***	-0.109***							
	(0.027)	(0.033)	(0.041)	(0.036)	(0.027)	(0.045)	(0.022)							
Central-SSA	-0.110***	-0.181***	-0.075*	-0.161***	-0.110***	-0.149***	-0.135***							
	(0.023)	(0.045)	(0.039)	(0.043)	(0.023)	(0.038)	(0.026)							
Southern-SSA	0.069***	0.002	0.035	0.073***	0.069***	0.034	-0.075*							
	(0.016)	(0.030)	(0.039)	(0.017)	(0.016)	(0.024)	(0.044)							
WGI	-0.087***							-0.111***						
	(0.015)							(0.012)						
CC		-0.124***							-0.077***					
		(0.021)							(0.016)					
GE			-0.001							-0.023**				
			(0.013)							(0.011)				
PV				-0.030***							-0.003			
				(0.011)							(0.004)			
RQ					-0.092***							-0.117***		
					(0.016)							(0.012)		
RL						-0.096***							-0.047***	
						(0.014)							(0.016)	
VA							-0.097***							-0.022***
							(0.018)							(0.006)
LMIC								0.186***	0.131***	0.223***	0.256***	0.186***	0.236***	0.300***

(*continued on next page*)

Table 4 (*continued*)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
								(0.032)	(0.048)	(0.032)	(0.038)	(0.032)	(0.030)	(0.028)
UMIC								0.315***	0.164**	0.212***	0.293***	0.315***	0.274***	0.364***
								(0.047)	(0.078)	(0.076)	(0.063)	(0.047)	(0.051)	(0.056)
HIC								0.125	0.007	0.177	0.171*	0.125	0.122	0.311***
								(0.122)	(0.098)	(0.109)	(0.103)	(0.122)	(0.085)	(0.110)
Constant	-1.135***	-0.286	-0.631*	-0.337	-1.137***	-0.479**	-0.305	-0.395	-0.007	-0.161	0.420***	-0.397	-0.078	0.385***
	(0.158)	(0.287)	(0.335)	(0.399)	(0.159)	(0.200)	(0.251)	(0.250)	(0.124)	(0.137)	(0.148)	(0.250)	(0.132)	(0.131)
Observations	393	393	393	393	393	393	393	393	393	393	393	393	393	393
Hansen	30.297	22.012	27.111	22.329	30.322	19.218	23.605	32.237	26.272	25.484	32.905	32.233	31.109	32.860
Hansen p-value	0.695	0.957	0.827	0.952	0.693	0.986	0.990	0.885	0.979	0.984	0.867	0.885	0.912	0.869
AR (1)	0.047	0.045	0.036	0.019	0.047	0.020	0.015	0.004	0.005	0.004	0.002	0.004	0.004	0.002
AR (2)	0.432	0.524	0.290	0.379	0.431	0.588	0.217	0.431	0.934	0.824	0.780	0.432	0.382	0.737

Standard errors in parentheses. Hansen-test refers to the over-identification test for the restrictions in the dynamic system-GMM estimation. The AR (1) and AR (2) tests are the Arellano–Bond tests for the first and second-order autocorrelation in first differences. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5
Condition effect of governance and access to credit on clean cooking technologies in SSA.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
L.lnclean	0.932***	0.920***	0.958***	0.916***	0.932***	0.929***	0.929***
	(0.011)	(0.014)	(0.018)	(0.017)	(0.011)	(0.013)	(0.014)
lnrgdpc	0.154***	0.157***	0.104***	0.177***	0.154***	0.135***	0.142***
	(0.021)	(0.029)	(0.033)	(0.022)	(0.021)	(0.025)	(0.020)
lnsse	0.012	0.010	0.012	-0.007	0.012	0.031***	0.008
	(0.010)	(0.007)	(0.011)	(0.014)	(0.010)	(0.008)	(0.010)
lnrural	0.039*	0.006	0.027*	0.052***	0.039*	0.031	0.008
	(0.022)	(0.023)	(0.015)	(0.016)	(0.022)	(0.020)	(0.019)
lnurban	-0.007	0.006	-0.009	-0.035*	-0.007	-0.019	0.019
	(0.021)	(0.022)	(0.015)	(0.018)	(0.021)	(0.020)	(0.019)
lndcpf	-0.026***	-0.045***	-0.042***	-0.036***	-0.026***	-0.046***	-0.017***
	(0.005)	(0.004)	(0.009)	(0.004)	(0.005)	(0.006)	(0.004)
WGI	-0.051***						
	(0.012)						
WGI × lndcpf	-0.006*						
	(0.003)						
CC		0.083***					
		(0.015)					
CC × lndcpf		-0.047***					
		(0.006)					
GE			0.078***				
			(0.027)				
GE × lndcpf			-0.032***				
			(0.009)				
PV				0.078***			
				(0.015)			
PV × lndcpf				-0.042***			
				(0.007)			
RQ					-0.054***		
					(0.013)		
RQ × lndcpf					-0.006*		
					(0.004)		
RL						0.044***	
						(0.015)	
RL × lndcpf						-0.033***	
						(0.005)	
VA							0.040***
							(0.014)
VA × lndcpf							-0.031***
							(0.005)
Constant	-1.403***	-1.008***	-0.812***	-1.214***	-1.405***	-0.974***	-1.217***
	(0.186)	(0.200)	(0.239)	(0.162)	(0.186)	(0.198)	(0.160)
Observations	393	393	393	393	393	393	393
Hansen	28.986	24.707	24.292	24.047	29.009	25.478	35.129
Hansen p-value	0.994	0.999	0.999	1.000	0.994	0.999	0.956
AR (1)	0.006	0.013	0.006	0.005	0.006	0.008	0.008
AR (2)	0.625	0.567	0.663	0.608	0.623	0.634	0.865

Standard errors in parentheses. Hansen-test refers to the over-identification test for the restrictions in the dynamic system-GMM estimation. The AR (1) and AR (2) tests are the Arellano–Bond tests for the first and second-order autocorrelation in first differences. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

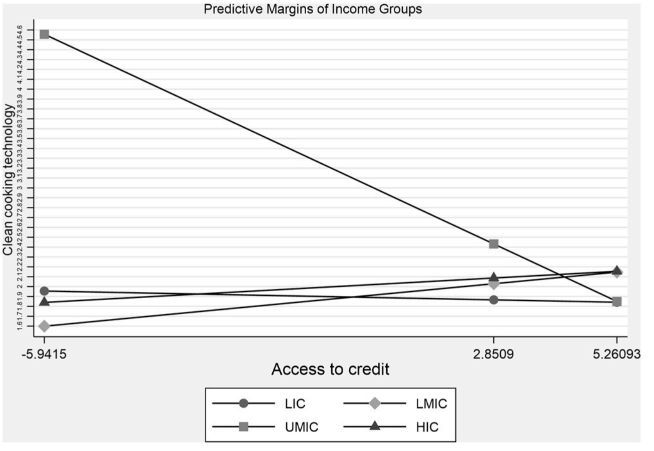

Fig. 2. Predictive marginal effects of access to credit on clean cooking technologies by income groups.

4.2. Does the effect of governance and access to credit on clean cooking technology usage differ among income groups in SSA?

In this sub-section, we examine if the difference in access to credit and governance among income groups has a disparate effect on access to clean fuels and cooking technologies. Fig. 2 shows that the slope of access to credit is negative for low-income and upper-middle income countries while being positive for lower-middle and high-income countries. This suggests that access to credit improves accessibility to clean fuels and technologies for lower-middle and high-income countries while impeding clean cooking technology usage in low-income and upper-middle-income countries. This result is contrary to Murshed’s (2022) findings that access to credit does not affect access to clean cooking technologies in low-income countries but accelerates the usage of clean cooking technologies in upper-middle-income countries in SSA.

In Fig. 3, the estimates suggest that the composite governance index slope is positive for lower-middle income countries while negative for low-income, upper-middle, and high-income countries. This finding indicates that, generally, governance improves the adoption of clean cooking technologies in lower-middle income countries while impeding clean cooking technology usage among the other income groups in SSA. On the specific governance indicators, the corruption control slope is negative for all income groups, suggesting that the state of control of corruption does not promote the development and usage of clean cooking technologies usage among the income groups in SSA. The policy implication is that uprooting corruption is necessary for boosting investment in developing clean fuels and cooking technologies among the income groups in SSA. Also, government effectiveness positively correlates with clean cooking technologies in lower-middle countries while negative for low-income, upper-middle and high-income countries. This result suggests that in lower-middle income countries, high quality of public and civil services and governments’ credibility and commitment to formulating and implementing energy policies are driving the development and adoption of clean fuels and cooking technologies compared to low-income, upper-middle and high-income countries in SSA.

Fig. 3 also shows that political stability has a positive relationship with clean cooking technologies in low-income countries and a negative association in lower-middle, upper-middle,

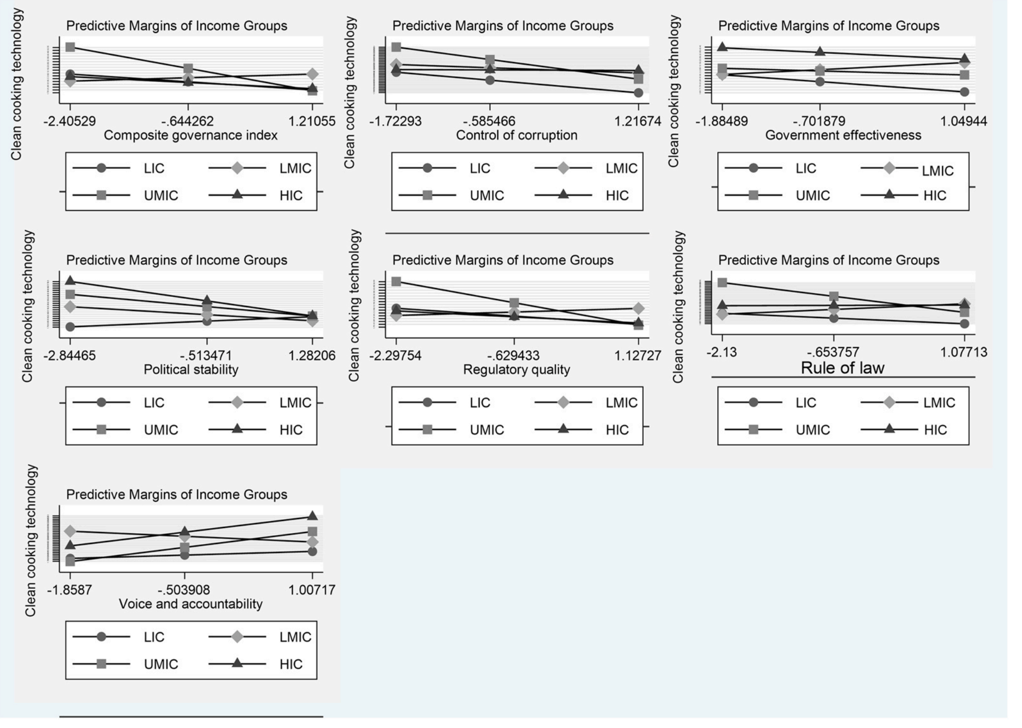

Fig. 3. Predictive marginal effects of governance on clean cooking technologies by income groups.

and high-income countries. This result indicates that improving and sustaining a stable political environment in lower, upper-middle, and high-income countries is essential for attracting investment in developing clean fuels and cooking technologies. It is further observed in Fig. 3 that the slope of regulatory quality is positive for lower-middle income countries and negative for low-income, upper-middle and high-income countries. This finding implies that in lower-middle income countries, the government's ability to formulate and implement sound policies and regulations that permit and promote private sector development has been effective in promoting access to clean fuels and technologies for cooking compared to low-income, upper-middle and high-income countries. Also, rule of law has a positive relationship with clean cooking technologies in lower-middle and high-income countries and negative for low-income, and upper-middle countries, indicating that contracts enforcement and protection of property rights in lower-middle and high-income countries have been effective in promoting accessibility to clean fuels and technologies for cooking compared to low-income and upper-middle income countries in SSA.

Further, it is observed in Fig. 3 that voice and accountability has a negative relationship with clean cooking technologies in lower-middle income countries while having a positive in low-income, lower-middle, and high-income countries. On average, the positive impact of voice and accountability on access to clean fuels and technologies for cooking is highest for high-income countries, followed by upper-middle-income and low-income countries, respectively. This finding shows the role of media freedom, freedom of expression, and association in advocating for policies that are consistent with people's needs, such as improving access to clean fuels and

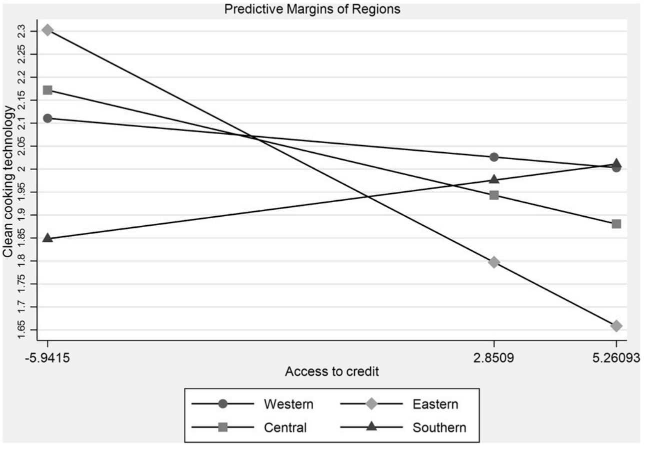

Fig. 4. Predictive marginal effects of access to credit on clean cooking technologies by regional groups.

technologies for cooking are effective in low-income, lower-middle, and high-income countries and not lower-middle income countries. Generally, these findings indicate that each governance variable has a disparate effect on adopting clean cooking technologies when considering the stages of economic development among SSA countries.

4.3. Does the effect of governance and access to credit on clean cooking technology usage differ among subregions in SSA?

In this section, we examine the variation in the effect of governance and access to credit on clean cooking technologies among the SSA sub-regions. The results are presented in Figs. 4 and 5. Fig. 5 shows that access to credit slopes for Western, Eastern and Central African countries are negative and positive for Southern African countries. These findings can be attributed to the difference in financial development among the regions. Studies on SSA's financial system have revealed that Southern African countries have better developed financial systems relative to Western, Central, and Eastern African countries (see Allen, Otchere, & Senbet, 2011; Acheampong, 2019). Therefore, that producers and consumers of clean fuels and cooking technologies in Southern African countries have easy access to credit to expand the production and consumption of clean cooking technologies. Contrarily, the relatively high credit constraints in Western, Eastern, and Central African countries limit access to clean fuels and technologies for cooking.

The regional effects of governance on clean fuels and cooking technologies are presented in Fig. 5. From Fig. 5, the slope of the composite governance index is positive for Central and Southern African countries while negative for Western and Eastern African countries. Generally, this finding indicates that governance has played a vital role in improving access to clean fuels and technologies for cooking among Central and Southern African countries. Contrarily, Western and Eastern African countries' governance has not been favorable in improving access to clean fuels and cooking technologies. Also, on the specific governance indicators, the slope of control of corruption is negative for Western and Eastern African countries while being positive for Central and Southern African countries. This finding implies that corruption is an

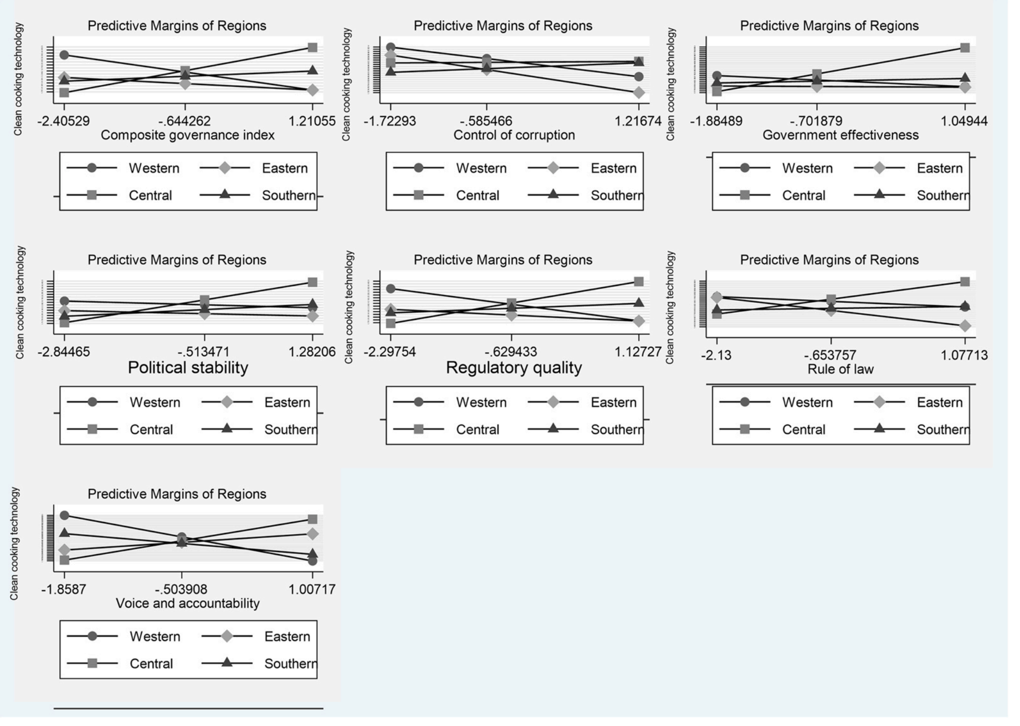

Fig. 5. Predictive marginal effects of governance on clean cooking technologies by regional groups.

obstacle to improving access to clean fuels and cooking technologies among Western and Eastern African countries. However, in Central and Southern African countries, control of corruption has provided the enabling environment to attract investment in the production of clean fuels and technologies for cooking. Also, the government effectiveness slope is positive for Central and Southern African countries while negative for Western and Eastern African countries, indicating that government effectiveness has improved access to clean fuels and technologies for cooking in Central and Southern African countries.

It is observed in Fig. 5 that in Southern and Central African countries, political stability, regulatory quality, and the rule of law have a positive relationship with access to clean fuels and technologies for cooking, while a negative relationship is observed for Western and Eastern African countries. The implication is that in Central and Southern African countries, a sound political environment, the credibility of government policies, and enforcement of rule of law have contributed significantly to improving access to clean fuels and technologies for cooking. Finally, the voice and accountability slope is positive for Central and Eastern African countries while negative for Southern and Western African countries, indicating that media freedom, freedom of expression, and the association has effective in enhancing accessibility to clean fuels and technologies for cooking are effective in Central and Eastern Africa countries. These regional analyses show that the governance indices have a different impact on access to clean fuels and technologies for cooking among the sub-regions in SSA.

5. Policy implications for energy transition in SSA

Globally, SSA is the region with the least access to clean fuels and cooking technologies. This suggests the region is off track in achieving universal access to modern and clean cooking fuels and technologies by 2030. IEA's policy scenarios show that 100% of SSA's population will have access to clean fuels and cooking technologies by 2030.[6] We argue that given the current state of traditional fuels and cooking technologies usage in SSA, rapid action is needed to scale up clean fuel and cooking technologies; otherwise, such scenario prediction would only be a mirage. In other words, it would be far from the reality for 100% of SSA's population to have access to clean fuels and technologies for cooking by 2030, as predicted by the IEA's policy scenario, if there is access to credit constraints and a weak governance system. This study contributes significantly to global policy discussions and the Africa Energy Commission's plan to accelerate energy transition in SSA by examining the effect of access to credit and governance on access to clean fuels and technologies for cooking. Our study has established that fundamental factors such as access to credit (finance) and governance impede the accessibility to clean fuels and cooking technologies in SSA. Also, the conditional effect analysis revealed that the governance variables moderate the effect of access to credit to impede the adoption of clean fuels and cooking technologies in SSA. The policy implications of these findings for the energy transition agenda in SSA are discussed as follows:

The role of access to credit in hindering access to clean fuels and cooking technologies suggests that finance will be a major challenge in SSA's energy transition agenda. This observation is not far from the truth, as SSA has a relatively poor financial system. With a poor and undeveloped financial system, investors could borrow to finance the development of clean fuels and technologies for cooking technologies at a very higher cost, which could deter the production and supply of clean cooking technologies. Also, even if investors could borrow at relatively high costs to produce and supply clean cooking technologies, it would not attract many consumers. Hence, borrowing at a high cost to produce clean cooking technologies implies a higher market price for the product, which would decrease its market demand. In addition, as urban dwellers have been the target of the clean cooking technologies market, most still rely on biomass and other dirty cooking fuels that are cheaper than clean cooking technologies. Therefore, there is a need to finance the production and consumption of clean cooking technologies at a lower cost. While financing is a challenge in the region, crowdfunding, charitable organization funding, and other innovative financing options could support the agenda of scaling up the adoption of clean cooking technologies in SSA. Currently, an innovative clean cooking technology financing program that needs to scale up in the region is the Modern Cooking Facility for Africa (MCFA) program. The MCFA program seeks to provide access to clean cooking technologies and solutions to approximately 3 million people in the region by 2027. This financing program is available to six sub-Saharan African countries: the Democratic Republic of the Congo, Kenya, Mozambique, Tanzania, Zambia, and Zimbabwe.[7] The MCFA also supports local companies that produce clean cooking technologies and further encourage the entry of new private companies into the production and supply of clean cooking technologies and solution in the operating countries through

[6] https://www.iea.org/data-and-statistics/charts/access-to-clean-cooking-in-the-sustainable-development-scenario-2010-2030.

[7] https://www.moderncooking.africa/.

funding.[8] In addition to the MCFA program, regional multilateral development financing institutions, domestic financial institutions, private investors, and other regional corporate entities should be committed and support the region's energy transition plan. This could be done by incorporating financing and distribution of clean fuels and technologies for cooking in their organizational sustainability objectives and corporate social responsibilities.

Also, our study revealed that governance (control of corruption, government effectiveness, political stability, regulatory quality, the rule of law, and government accountability) is a challenge in improving accessibility to clean fuel and technologies for cooking in SSA. This result further adds to Acheampong et al. (2022) observation that governance has been unfavorable in reducing energy poverty in SSA. In line with Acheampong et al. (2022) argument, a weak governance system that characterizes SSA renders energy policies ineffective. Since the inception of the SDGs in 2015, SSA governments have been implementing numerous energy policies and reforms to boost the adoption of clean energy in the region; however, less than 20 % of the people in SSA do not use clean cooking technologies. Most energy policies and programs implemented to boost the usage of clean fuels and technologies for cooking in SSA have failed or have been ineffective because of partisan politics and poor planning and implementation, which are symptoms of weak governance. For instance, evidence suggests that under Ghana's Rural Liquefied Petroleum Gas Program (RLP) in 2013, LPG cookstoves were distributed based on political affiliation (Asante et al., 2018). Also, Ghana's Rural LPG program was poorly designed and implemented because the LPG cookstoves were distributed to villages that lacked the infrastructure to supply them with LPG. To support this assertion, Asante et al. (2018), in evaluating Ghana's Rural LPG program, conclude that:

> …evaluation of the RLP in five rural communities showed that about 58 % of households had never refilled their LPG cylinders nine months after the initial delivery of a filled cylinder. Only 8 % still used their LPG at 18 months post distribution. Cost and distance to LPG filling stations were the main reasons for low LPG use. Beneficiaries did not exclusively use their LPG even at the initial stages when all of them had LPG in their cylinders.

This evidence is a clear case of energy policy failure, which can be attributed to poor governance in the formulation and implementation of energy policies and programs in SSA. We argue that improving access to clean cooking technologies in SSA requires an effective governance system devoid of corruption and partisan politics. Also, enforcing contracts and property rights protection and rewarding clean cooking technologies developers (inventors) would contribute significantly to the production and accessibility of clean cooking technologies in the region.

6. Conclusion

There is a global effort toward reducing or eliminating dirty cooking technologies due to their severe health and economic implications. Reducing dirty energy usage requires an effective transition towards clean cooking technology usage. However, not much is known empirically about the role of access to credit and governance in the transition towards clean cooking technologies usage, especially in developing countries. This study, therefore, utilizes

[8] https://www.nefco.int/news/increased-financing-for-clean-cooking-modern-cooking-facility-for-africa-to-launch-its-first-funding-round-soon/.

the two-step-dynamic system generalized method of moment estimator to investigate the effect of access to credit and governance on the adoption of clean cooking technologies in (SSA). The findings indicate that access to credit and governance variables do not facilitate clean cooking technologies usage. Conditional effect analysis also reveals that the governance variables moderate the effect of access to credit to impede clean cooking technology usage. The findings further indicate that other factors, such as economic growth, education, and rural population, drive clean cooking technology usage. Sensitivity checks show that the effect of access to credit and governance on clean cooking technology usage differs among income and regional groups within SSA.

From a policy perspective, we contend that a successful transition towards clean fuels and cooking technologies in SSA depends on access to credit (finance) and the effectiveness of governance in the region. Our study highlighted the potential of increasing clean fuels and technologies for usage among rural folks. However, a significant problem associated with using clean fuels and cooking technologies such as LPG among rural folks in SSA is the need for them to travel a long distance to get their LPG cylinders (re)filled and, to some extreme cases, greet with a shortage of LPG in some of the nearest LPG filling stations. Therefore, scaling the usage of clean fuels and cooking technologies among rural folks is to expand clean energy infrastructures in these areas and ensure a consistent supply of LPG to the nearest LPG filling centers. Also, our study suggests that sound macroeconomic and social policies that support economic growth and human capital development are crucial for effective transition toward clean fuels and cooking technologies in SSA. Finally, our study recommends the need for energy policymakers, specifically the African Energy Commission, to incorporate structural and institutional differences among countries in designing and implementing the region's energy transition policy and program.

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