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Fintech, human development and energy poverty in sub-Saharan Africa

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A B S T R A C T

Studies have highlighted the important role of financial technology (fintech) in enhancing socio-economic conditions of nations. However, despite the efforts of governments to improve the latter, the rating of African countries still remains manifestly inadequate. Given that access to electricity is imperative for fintech, and fundamental to improving socioeconomic conditions, we provide novel evidence by investigating the degree to which the prevailing energy poverty in Africa mediates the relationship between the duo. Our baseline results confirm that fintech has a significant positive impact on socioeconomic conditions, proxied by human development, and the impact becomes increasingly significant in the face of constant energy supply. However, when we split our sample based on regions and income classification proposed by the World Bank, our results show that the impact of fintech on human development, in the absence of access to electricity, is notably limited to some African regions. Considering the current state of human development in Africa, our study advocates for more investment in energy infrastructure for the rapid realization of the gains of fintech.

1. Introduction

Over the years, the goal of improving socioeconomic conditions has been critical to the design of countries' economic programs, with the human development index (HDI) serving as the primary indicator of a country's socioeconomic status. HDI is a tool developed by the United Nations to supplement metrics on economic growth and development. It evaluates the wellbeing and quality of life of a country's populace, thus placing greater emphasis on the capabilities and functioning of residents rather than the country at large (Chakravarty, 2003; Yumashev et al., 2020). HDI is significant because it directs the attention of governments towards implementing policies that not only improve the economy but also enhance human welfare. Therefore, it has both social and economic dimensions. The social dimension of HDI assesses health, life expectancy at birth, and access to information and knowledge, whereas the economic dimension emphasises living standards and average income (Hickel, 2020). A score of at least 0.80 indicates that the country in

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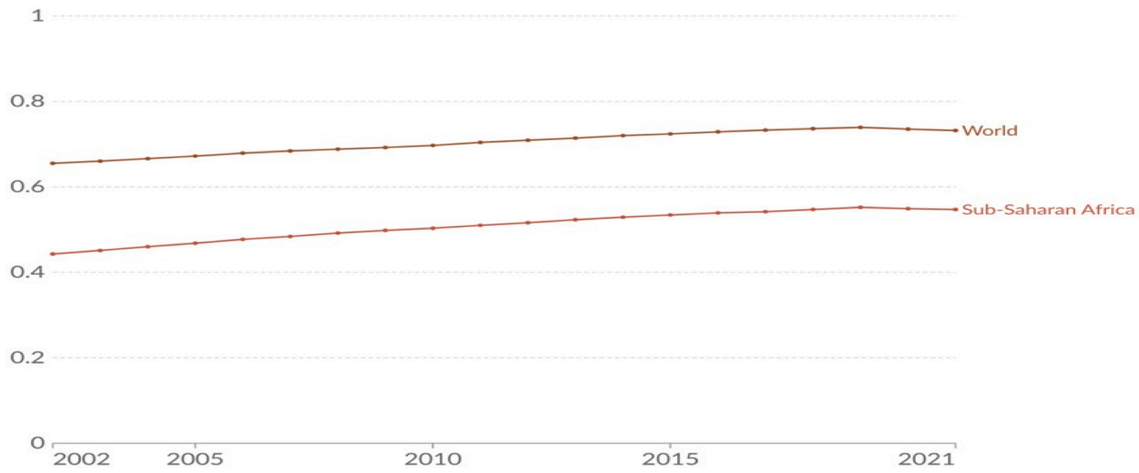

Fig. 1. Human Development Index in Sub-Saharan Africa and the world. Source: United Nations Development Programme.

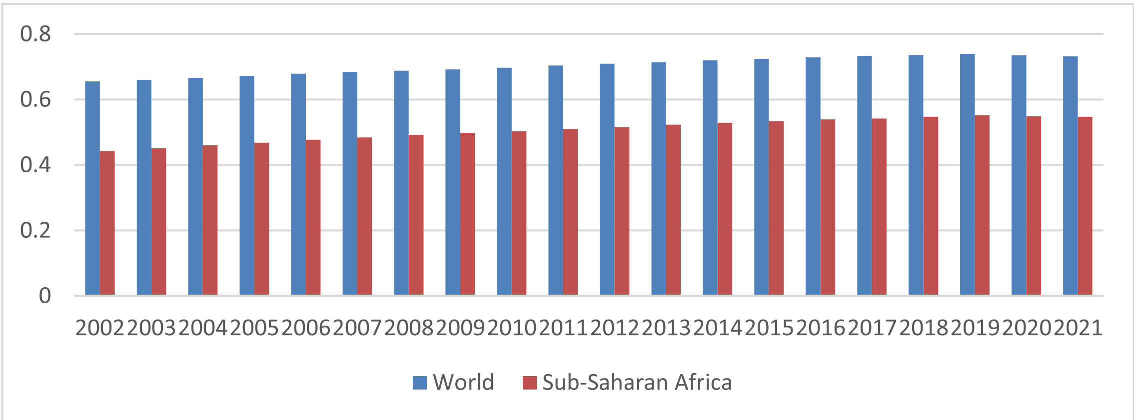

Fig. 2. Chart of Human Development Index in Sub-Saharan Africa and the world.

question rates highly in both social and economic dimensions.

Given the numerous benefits associated with human development, vast majority of countries have embraced HDI yardsticks, in a concerted effort to improve their socioeconomic conditions. Meanwhile, in Africa, despite efforts to raise HDI, African countries' rankings on the index table remain low. Although countries in Africa have increased budgetary spending on the metrics of HDI such as education, health, and information and communications technology (ICT), the consequences have been widely disparate. According to a recent study, only a few Sub-Saharan African nations, including Seychelles, Mauritius, Botswana, South Africa, and Gabon, as well as a number of North African countries, have seen a rise in HDI during the last decade (Sarkodie & Adams, 2020). The evidence in Figs. 1 and 2, which displays the average HDI scores for sub-Saharan Africa and the world, over our sample period (2002–2021), confirms that human development is much lower in sub-Saharan African countries than the world average. In particular, the mean HDI score in sub-Saharan Africa in 2021, the final year of our study sample, was still below the mean HDI score for the world at the start of the study sample in 2002. The continuing low-level HDI ranking of African countries impedes the continent's overall development and prevents its citizens from harnessing their potentials. Africa thus provides a unique opportunity to learn more about the following question: What factors promote (or impede) human development? This study offers a novel and profound answer to this important question.

A growing body of research in the broader economics and finance literature have identified various factors that boost human development in both developed and emerging markets. Essentially, a strand of the literature emphasizes the critical role of fintech. Proponents of fintech argue that its efficient use can protect the most disadvantaged in the society (Owusu-Agyei et al., 2020). For instance, studies argue that through technological innovations, fintech enhances financial inclusion (Ahmed, 2016; Tekin, 2020), reduces transaction cost (Wang et al., 2019), provides access to faster and cheaper finance among the poor (Tekin, 2020), increases literacy rate through information sharing (Owusu-Agyei et al., 2020), creates job opportunities for citizens (Hussain et al., 2021) and reduces poverty and inequality (Ofosu-Mensah Ababio et al., 2021), all of which positively affect human development. On the contrary, critics of fintech argue that it can be a source of economic instability and political manipulations (Guo et al., 2023). Others opine that fintech is not eco-friendly, because of the enormous amount of energy needed to run and process computer software and hardware

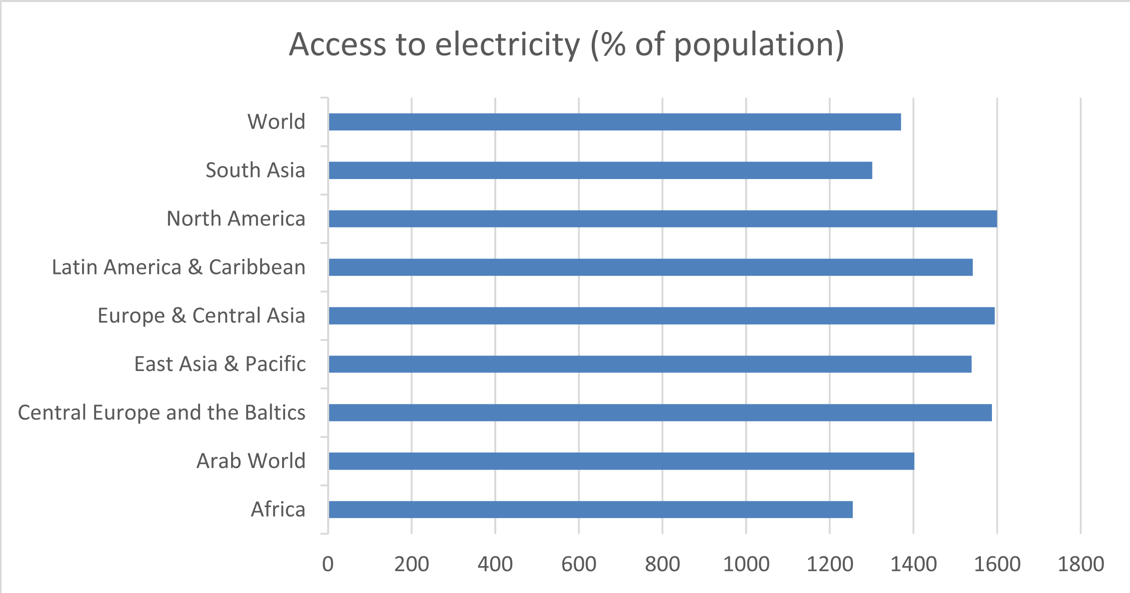

Fig. 3. Africa's access to electricity (as % of population) compared to the rest of the world.

(Chen et al., 2021). Besides, studies show that fintech adoption could lead to transfer of financial crises and risks from developed nations to emerging ones (Guo et al., 2023).

Notwithstanding the above drawbacks, fintech development is rapidly expanding and has become increasingly integrated into the economic strategies of most nations. Indeed, literature surmises that the impact of fintech on human development largely depends on macroeconomic and institutional quality variables such as GDP, corruption, domestic savings, rule of law, transparency, and efficiency of the domestic financial system (Ahmed, 2016; Sarkodie & Adams, 2020). For example, countries are less likely to attract investments into their fintech ecosystem if they have poor corporate governance structures and frequent economic instability. While studies have explored the fintech-governance nexus, we reckon from a novel perspective that another crucial aspect of examining the impact of fintech on human development, especially in Africa, is to consider the prevalence of energy poverty. The development and adoption of fintech is deemed to rely heavily on energy sources which are in acute shortage in several parts of Africa. Andersen & Dalgaard (2013) note that a significant proportion of sub-Saharan Africans do not have constant access to electricity, and the erratic supply has forced many African firms and households to pay a chunk of their incomes to provide their own electricity. The data presented in Fig. 3, which illustrates the global and African average access to electricity during the sample period, provides additional support for the notion that energy poverty is pervasive in African nations. This situation hinders the continent's ability to fully exploit the opportunities presented by fintech.

Electricity connects everything in the technological world, and to this end, fintech may not achieve the intended goal of improving HDI in Africa if there is persistent energy constraints. As a nation's population increases, so does its energy demand. The literature has seen a surge of interest in the relationship between fintech and human development, with mixed results (Daniela & Sally, 2017; Tekin, 2020; Owusu-Agyei et al., 2020; Ofosu-Mensah et al., 2021). However, to the best of our knowledge, research on how energy moderates the duo remains unaddressed in the literature. Filling this research vacuum is imperative given that a reliable electricity supply is at the heart of fintech and human development. As a result, in our empirical analysis, we interact fintech variables with proxies for energy poverty, to determine the marginal and net effects on HDI. By doing so, we depart from previous studies that only addressed non-interactive regressions. The net effect approach, which permits the simultaneous introduction of energy poverty as a moderating variable, provides policy-relevant insights regarding macroeconomic outcomes (Asongu & Nwachukwu, 2016; Sakariyahu et al., 2023).

To achieve the study's objectives, we use a panel data comprising of 43 countries in sub-Saharan Africa. Our baseline results show that fintech has a significant positive impact on human development, implying that the use of financial technology increases the social and economic conditions of the populace in sub-Saharan Africa. Furthermore, we explore the net and marginal interaction effects of access to electricity and fintech on HDI and find positive and significant net effect at 1 % level of significance for nations characterised by moderate levels of electricity accessibility. While the marginal interaction effect is negative for levels up to the 25th percentile, significant and positive marginal effects are observed for the higher percentiles of access to electricity. Intuitively, the result connotes that the interaction variables would have a combined significant long-term and average positive impact on HDI in Africa. Additionally, we split our sample based on regions and income classification proposed by the World Bank. Our results show that the impact of fintech on HDI, without interaction with access to electricity, is more visible in the upper-middle and high-income countries. The low-income countries have not significantly benefitted from fintech adoption, perhaps because countries in the low-income category have a high prevalence of energy challenge. In addition, we find that the effect of fintech on HDI is pronounced in Eastern, Central and Southern regions. It is, however, surprising that an insignificant relationship is registered for the Western region. This is perhaps because most of the countries in the Western region fall in the lower-income category and face acute energy crisis. This confirms that fintech may not accomplish the goal of improving HDI in Africa if energy crisis persists. Lastly, we introduce quantile regressions as a robustness to cater for the fact that countries' HDI characteristics are not the same across a given distribution of fintech measures. We therefore examine whether the impact of fintech on HDI across the quantiles, changes over time with distribution. Our findings do not materially differ from the baseline results. Notably, our results reflect significant implications for key stakeholders such as governments, development agencies, and policy makers.

Against this background, and in the light of the current state of human development in Africa, this study contributes to academic literature on several fronts. First, we extend prior studies on human development by demonstrating that an improvement in HDI is a *sine qua non* for the prosperity of the African continent. Research on human development (such as Ranis et al., 2006; Harttgen & Klasen, 2012; Sarkodie & Adams, 2020) argues that countries that place strong emphasis on HDI tend to witness rapid economic growth and development. The findings of our study further reinforce this position. Second, we contribute to the extant literature on fintech by demonstrating the significant role it plays in improving HDI and how energy poverty in the African region limits its impact. Despite the abundance of studies in financial literature exploring the linkage between fintech and human development, less attention has been paid to the influence of energy supply. Our study therefore complements prior studies to advocate for more investment in energy infrastructure for the rapid realization of the gains of fintech. We opine that a significant improvement in access to constant electricity will motivate fintech usage among economic units and spur a positive impact on HDI. Third, by stratifying our sample into regions and income classification, we render more far-reaching insights into the peculiar plights of each region, rather than a composite evaluation. This approach offers valuable information for development institutions and other key stakeholders in providing unique solutions to the current HDI status of the African region. Finally, from a theoretical perspective, our results are consistent with the *internet growth and contestable market theory* (Asongu & Le Roux, 2017; Demirgüç-Kunt et al., 2018; Owusu-Agyei et al., 2020; Emara, 2022), as well as *energy consumption-growth hypothesis* (Apergis & Payne, 2010; Apergis & Tang, 2013; Raza et al., 2015). These theories postulate that greater use of internet facilities, amid stable electricity, especially by disadvantaged units in an economy, propels an increase in standard of living and improves economic growth.

The remainder of this paper is structured as follows. In section 2, we give some background to our study by reviewing related studies in the literature that have considered fintech and human development and providing a brief overview of the relevant institutional developments in Africa. In section 3, we provide details of our data and methodology. Our empirical findings, significance, and policy implications are presented in section 4. Finally, the paper is concluded in section 5.

2. Literature review

The theoretical background of our study stems from the finance-growth literature that is focussed on how development in the financial sector enhances economic development. Ang (2008) argues that this is made possible through two main channels: total factor productivity (qualitative channel) and capital accumulation (quantitative channel). The total factor productivity channel comes into play when the financial system makes use of information technology to enhance the development of a country's industries by providing efficient credit facilities and such other innovative financial services as required by economic units. Likewise, Wachtel (2001) identifies the promotion of higher savings rates, through the provision of attractive and innovative products to encourage savings mobilization, as one of the channels through which financial development influences economic development of a country. These assertions suggest that technological innovations in financial services and products are necessary inputs that would positively influence the economic and social wellbeing of economic units. Financial technology may generally be defined as applying innovative technology to improve financial activities that would otherwise not be available to some economic units (Leong & Sung, 2018; Schueffel, 2016). With the adoption of fintech, it is expected that these units would have improved access to financial services, savings mobilization, and access to credit facilities that would impact positively on human capital development, health, and education, which are all major components of human development (Demirgüç-Kunt et al., 2018; Matekenya et al., 2020). Human development, as espoused by Nussbaum (2000), includes a set of policy targets such as health, integrity, property rights and affiliation etc. that improve the living standards and well-being of individuals in an economy. Going further, the United Nations Development Program (UNDP) in 2018 refines the concept of human development to include improvement in health and education and political/institutional freedom. It is computed as the geometric average of three normalised indices encapsulating enjoying a long and healthy life, being knowledgeable, and possessing a decent standard of living, all of which are core policy targets for most national governments.

In line with the total factor productivity channel, some studies adopted the *internet growth and contestable market theory*, while drawing on the *unified theory of acceptance and use of technology* (UTAUT), to explain the ways through which use of technology influences financial access and ultimately improves the standard of living conditions of economic units as championed by the HDI (see, for instance, Asongu & Le Roux, 2017; Owusu-Agyei et al., 2020; Goel & Hsieh, 2002). The *internet growth and contestable market theory* outlines that internet usage mostly by disadvantaged units in an economy leads to increased financial access and greater competition due to lower transaction costs, reduction in both entry barriers and information asymmetry. In addition, the UTAUT provides plausible reasons that account for differences in internet adoption and use in different countries. These include the geographical setting and institutional quality of countries (Wang and Wang, 2010).

The activities relating to fintech include, but are not limited to, mobile banking, mobile payments and blockchain technology. The moderating role of energy in fintech adoption is viewed from the supply side of access to electricity and communication facilities (Yermack, 2018) such that access to reliable and constant electricity to power the mobile tools would encourage the adoption and use of fintech. For our study, we make use of fintech index and include access to electricity as one of the reasons that may explain the cross-country differences in adoption. Further buttressing the *internet growth and contestable market theory* is the growth in recent studies that examined the use of fintech in developing countries to enhance financial inclusion and improve access to financial services in disadvantaged, or unbanked locations (Chhorn, 2021; Chinoda & Mashamba, 2021; Demirgüç-Kunt et al., 2018; Emara, 2022; Tekin, 2020). Based on the preceding theoretical discussions, we hypothesize that fintech adoption enriches human development with access to electricity playing a moderating role in the relationship in sub-Saharan African countries.

Empirical literature on the relationship between fintech and human development has produced mixed results. Several studies argue that fintech adoption in developing countries contribute to improvement in human development index through social welfarism. For instance, Apiors and Suzuki (2018) find that users of mobile money in Ghana have more savings, more investments in education and small businesses, resulting in a better way of life. Wieser et al. (2019) similarly document that in Uganda, mobile money transfer technology improved the welfare and financial position of money transfer recipients and the overall rural economy. Chhorn (2021), in a cross-country study of eight Southeast Asian countries for the period 1990 to 2017, report that fintech adoption (mobile money) positively affected HDI, irrespective of the economic, political, and institutional environment of the country. Also, Ofosu-Mensah et al. (2021), in a study of 20 frontier market economies, demonstrate that promoting financial inclusion through fintech adoption goes a long way in improving human development in the group of countries under investigation and recommended a holistic approach to implementing development policies that would enhance HDI. Other studies, such as Gomber et al. (2017), Jones (2018), and Lyons et al. (2020), analogously confirm the positive effects of financial technology adoption on the welfare and standard of living of economic units.

Despite the positive effect of fintech adoption, several studies show its weak effect with the argument that fintech adoption also depends on some factors such as institutional quality and rate of technology adoption, as well as the spill-over effect of fintech on other sectors of the economy. In a comparative study between Kenya and Jamaica, Minto-Coy & McNaughton (2016) argue that, in Kenya, the institutional framework is an important determinant influencing the level of adoption and success of innovation in financial technology usage through constant innovations and being up to date with changes in regulatory policies. This was, however, not the case for Jamaica, where the more developed regulatory environment, together with path dependency, obstructed the introduction and progress of mobile banking, a form of fintech (see also Johnson, 2016; Mbiti & Weil, 2015). Their findings strengthened the important role played by institutions in fintech adoption and its overall effect on a country's socio-economic status, proxied by HDI. Supporting this assertion, Asongu & Nwachukwu (2016) opine that governance and institutions play a principal role in the relationship between mobile money and inclusive human development in sub-Saharan Africa. Regarding other factors impacting the fintech-HDI nexus, Yermack (2018) notes that some of the significant barriers to fintech adoption in developing countries are electricity supply, communication infrastructures in place, and the political system in place. This connotes a supply-side problem such that residing in a country with a more reliable supply of electricity, devoid of frequent outages, would encourage the use of fintech services, thus implying the existence of a moderating effect of electricity in fintech adoption-HDI relationship.

3. Data and methodology

3.1. Data description

To evaluate the extent to which energy poverty affects the relationship between financial technology and human development, we construct our dataset as a panel of 43 countries in sub-Saharan Africa. The measurement and sources of variables as well as countries included in our sample are shown, respectively. The time span for this study covers from 2002 to 2021. Our choice of this period is for two reasons. First, the availability of data; some of the country-level variables adopted in this study are only available for these years, as at the time of writing. Second, we focus on this period due to the significance of the era; our timeframe falls within the United Nations Sustainable Development Goals (SDG) era, where several countries galvanized unprecedented efforts to meet 17 different goals, of which, part of the strategy to achieving these goals was human development. More so, within this timeframe, fintech witnessed significant growth in its dynamics, as more countries continued to adopt fintech tools to improve their socioeconomic conditions.

The dependent variable in our model is the yearly value of Human Development Index (HDI) for each sub-Saharan African country. The index is computed by the World Bank, with values ranging from 0 to 1 and covers both social and economic dimensions of each country. A country with a score of at least 0.80 is designated as a high human development country (see World Development Indicators database for further information on the characteristics of the variable). Prior studies that have used this index include Sarkodie & Adams (2020) and Matekenya et al. (2021).

Our set of explanatory variables contains indexes for fintech and institutional quality, as well as governance indicators to capture the macroeconomic environment of a country, with access to electricity acting as moderating factor. Following empirical postulations in the literature, we build a fintech index based on three measures: MPay which reflects the proportion of adults who utilise mobile money as a means of paying their bills; MStore represents the percentage of people who store their money using a mobile account and MAcct denotes the percentage of individuals who possess mobile money accounts. We believe these proxies have a positive impact on HDI because an increase in their provision and usage can improve financial literacy and raise socio-economic conditions of citizens. Moreover, studies (such as Asongu & Roux, 2017; Dorfleitner et al., 2019; Asongu et al., 2021; Ajide et al., 2023) have used these variables and report significant effects on both human and economic development.

The next independent variable is the institutional quality index which is constructed based on the following 6 measures: control of corruption, government effectiveness, political stability and absence of violence, rule of law, voice and accountability and regulatory quality (Wang & Wang, 2010; Sarkodie & Adams, 2020). Since we assume that the sampled countries are likely to be deeply integrated,

Table 1
Summary Statistics This table presents descriptive statistics of all the variables used in the analysis. Our base sample consists of 43 countries.

Variable	Mean	Std. Dev.	Min	Max
Dependent variable: HDI	0.512	0.103	0.274	0.794
Independent variables: Fintech Index	0.187	0.551	0.472	0.917
Access to Electricity	41.981	27.078	1.753	100.000
Control variables: GDP Per capita	3.804	0.607	2.634	5.092
Institutional Quality Index	0.018	0.996	0.105	0.769
Inflation	6.684	6.545	−4.295	52.766
Trade openness	72.482	35.501	20.722	225.023
Population Growth	2.472	0.944	−2.629	4.655

Table 2
Correlation matrix.

	1	2	3	4	5	6	7	8
1	1.0000							
2	0.1717*	1.0000						
3	0.8053*	0.0069	1.0000					
4	−0.0026	0.0913*	0.0564	1.0000				
5	0.4699*	−0.1355*	0.3396*	−0.0783	1.0000			
6	−0.0355	−0.0878	−0.1647*	0.0103	−0.0812	1.0000		
7	0.5744*	0.0209	0.4172*	−0.1219*	0.1380*	0.0332	1.0000	
8	−0.4827*	0.0624	−0.4185*	0.0853	−0.4000*	0.0384	−0.4251*	1.0000

* Shows significance at the 0.05 level.
1. HDI.
2. Fintech index.
3. Access to electricity.
4. GDP capita.
5. Institutional quality.
6. Inflation.
7. Trade openness.
8. Population growth.

it is plausible to expect the institutional index variable to help control the impact of such integration on HDI at country level. The macroeconomic indicators included are also driven by empirical arguments. They include: GDP per capita, a proxy used to measure the size of the economy and we expect it to relate positively with HDI (Asongu & Le Roux, 2017); inflation, a variable used to measure the purchasing power of the economy and we anticipate its increase will reduce HDI (Emara, 2022); population growth, a measure used to reflect a country's human capital and capture the increase (or decrease) in the number of people accessing a country's resources (Emara, 2022); and trade openness, which is used to measure a country's economic and trade freedom (Chinoda & Mashamba, 2021).

Lastly, we utilise energy poverty as the moderating variable proxied by access to electricity. We define energy poverty as a condition characterized by intermittent supply of electricity to households and firms (Sarkodie & Adams, 2020). We collect data for access to electricity from WDI's database of the World Bank. We further collect data on power generation as an alternative measure of energy poverty. For the sake of conciseness, our main estimations only include access to electricity as a moderating variable because the sign and size of the coefficients of the alternative measure -power generation- are comparable to those of access to electricity.

We report the descriptive statistics and correlation matrix in tables 1 and 2, respectively. As shown in Table 1, the mean of HDI is about 0.51. The minimum HDI is about 0.27 and this figure is observed for countries like Niger and Chad. The maximum HDI in the sample is about 0.71, which is observed for some South African countries. Regarding the fintech variable, the mean value is about 0.19, minimum is 0.47 and maximum is 0.92. The mean value of the energy poverty variable is about 41.98 %, indicating that on the average, access to electricity in the African region is relatively low. The table also shows that the minimum score is 1.75 and maximum of 100 % access to electricity is witnessed in some countries.

3.2. Model specification and estimation methods

We now turn our attention to the empirical strategy employed in this paper. Essentially, we begin our empirical estimation with a baseline regression as follows:

$$HDI_{i,} = a + \phi Fintech_{i,} + \theta electricity_{i,t} + \Psi(Fintech^{*}electricity)_{i,t} + \zeta Controls_{i,t} + \varepsilon_{it}$$

The equation provided above indicates the relationship between the explanatory and dependent variables. Specifically, $HDI_{i,t}$ represents the Human Development Index of a certain country i during a specific period or year t. The variable fintech refers to financial technology variables, while electricity represents the level of access to electricity. The term Fintech*electricity represents the interaction between fintech and access to electricity. The variable "controls" comprises a set of additional explanatory factors, encompassing institutional and governance factors. The error term, denoted as ε, represents the unobserved factors that contribute to

Table 3

The impact of Fintech on HDI This table reports the result of model 1 which assesses the relationship between Fintech and HDI based on Random Effect (RE), Generalised Linear Model (GLM) and Generalised Method of Moments (GMM). Coefficients are computed using standard errors robust to heteroskedasticity. Standard errors are shown in parentheses. The estimations include year and country effects. Definitions of variables and data sources are provided in Appendix. *, **, *** stand for levels of significance at 10%, 5% and 1% respectively.

VARIABLES	(1)	(2)	(3)
	RE	GLM	GMM
Fintech	0.0616***	0.0422***	0.0198***
	(0.0029)	(0.0082)	(0.0050)
GDP per capita	0.0300	0.0162*	0.0270***
	(0.0024)	(0.0093)	(0.0007)
Institutional Quality	0.0909**	0.0411***	0.0120
	(0.0383)	(0.0435)	(0.0287)
Inflation	−0.0150	0.0590	−0.0200
	(0.0012)	(0.0056)	(0.0040)
Trade Openness	−0.0500	0.0140***	−0.0600
	(0.0011)	(0.0012)	(0.0007)
Population Growth	−0.0508*	−0.0172***	−0.0630*
	(0.0272)	(0.0586)	(0.0037)
L.human_dev	–	–	0.6647***
			(0.0746)
Constant	0.5258***	0.4637***	
	(0.0196)	(0.0201)	–
Year effect	Yes	Yes	Yes
Country effect	Yes	Yes	Yes
Number of countries	43	43	43
Hansen stats	–	–	10.88 (0.540)
AR (1)	–	–	−2.66 (0.008)
AR (2)	–	–	1.57 (0.116)
Number of groups	–	–	38
Number of instruments	–	–	25

the variability in the dependent variable. On the other hand, α refers to the intercept, which represents the value of the dependent variable when all independent variables are equal to zero. The variable $\varnothing$ represents the influence of fintech on HDI when access to electricity and other variables are held at zero. The variable θ represents the impact of access to electricity on HDI when Fintech and other variables are equal to zero. The variable ψ captures the combined effects of Fintech and access to electricity on the dependent variable HDI. Lastly, the variable ζ quantifies the influence of other explanatory variables on the dependent variable.

Next, we describe our estimation methods in detail. We start with a random effect regression. The choice of random effect model is sequel to a series of specification tests. Generally, random-effect model is suitable when certain conditions are present. First, when the number of units (firm or country) in a panel data is relatively higher than the time span, using fixed-effect model will result in misspecification, the variance of the estimated parameters will be unnecessarily high due to significant loss of degree of freedom and the use of random effect model would be appropriate (Thomas et al., 2014). Second, fixed effect model is rather applied to observations that are specific to a firm or country. Considering the structure of our data (small T and large N), the random-effect model is most suitable, and this is further buttressed with the outcome of Hausman test which suggests no evidence to reject the null hypothesis, as shown.

Furthermore, a common assumption in panel data models is that the cross-sections exhibit an independent error term. However, according to Driscoll & Kray (1998), cross-sectional dependence might occur due to unobserved common shocks. In such circumstances, the estimated parameters may be inconsistent. Generally, cross-sectional dependence is common when the time span (T) is greater than the units (N). Our data, however, defies this condition, as the unit (N) is larger than the timespan (T). Nevertheless, we employ Pesaran (2004) parametric testing procedure for cross-sectional dependence and the results, shown confirm no evidence of cross-sectional dependence.

In order to address potential concerns related to non-normal distribution and the suitability of Poisson, Gamma, and Binomial distributions for modelling purposes (Nelder and Wedderburn, 1972), we employed a generalised linear model. The generalised linear model (GLM) is characterised by the inclusion of a monotonic link function g(). This function acts as an intermediary between the response variable y (representing HDI) and the predictor variables.

Also, a major concern in the use of panel data model is the presence of endogeneity which often leads to biased and inefficient estimates. We suspect endogeneity in some of the control variables, particularly the macroeconomic indicators. For instance, higher GDP per capita may increase HDI and vice versa while higher inflation may also have bi-directional causality with HDI. To correct for endogeneity problems and possible issues of reverse causality, we employ an instrumental variable method - Generalized Method of Moments (GMM)- to estimate the model. Unlike the static panel, the GMM estimator, as proposed by Arellano and Bond (1991), contains the lag of the dependent variable which eliminates individual effects while accounting for momentum and inertia.

Additionally, there may be concerns that some of the observed variations in the estimates of HDI may reflect the fact that country-characteristics are not the same across a given distribution of fintech. To examine this issue, we use quantile regression developed by Koenker (1978) which estimates the effect of regressors on the dependent variable at different points of the dependent variable's

Table 4

Moderating the impact of energy poverty on the relationship between Fintech and HDI This table reports the result of model 2 which assesses the relationship between Fintech and HDI with an inclusion of access to electricity as a moderating variable. Estimation is performed using Random Effect (RE), Generalised Linear Model (GLM) and Generalised Method of Moments (GMM). Coefficients are computed using standard errors robust to heteroskedasticity. Standard errors are shown in parentheses. The estimations include year and country effects. Definitions of variables and data sources are provided in Appendix. *, **, *** stand for levels of significance at 10%, 5% and 1% respectively.

VARIABLES	(1)	(2)	(3)
	RE	GLM	GMM
Fintech	0.0505***	0.0449***	0.0210***
	(0.0041)	(0.0511)	(0.0525)
Access to Electricity	0.0117***	0.0246***	0.0280**
	(0.0027)	(0.0011)	(0.0012)
GDP per capita	0.0202	0.0610	0.0260***
	(0.0025)	(0.0067)	(0.0070)
Institutional Quality	0.0112***	0.0245***	0.0570
	(0.0030)	(0.0029)	(0.0285)
Inflation	−0.0100	0.0189***	−0.0300
	(0.0011)	(0.0044)	(0.0040)
Trade Openness	0.0300	0.0770***	−0.0400
	(0.0011)	(0.0070)	(0.0060)
Population Growth	−0.0384*	−0.0321	−0.0670*
	(0.0223)	(0.0266)	(0.0350)
L.human_dev	–	–	0.5958***
			(0.0866)
Constant	0.4689***	0.3415***	
	(0.0174)	(0.0110)	–
Year effect	Yes	Yes	Yes
Country effect	Yes	Yes	Yes
Number of countries	43	43	43
Hansen stats	–	–	13.08 (0.363)
AR (1)	–	–	−2.54 (0.011)
AR (2)	–	–	1.39 (16.3)
Number of groups	–	–	38
Number of instruments	–	–	26

conditional distribution. We introduce quantile regressions, first, as a robust technique to cater for our estimations given that the standard assumption of normality of the error term might have been violated. Also, to get information about points in the distribution of the dependent variable other than the conditional mean (Baur, 2013). Quantile estimates are conditioned on the coefficients' location, scale, magnitude, and sign (Machado & Silva, 2019). We therefore determine the total impact of the regressors on HDI by partially taking the derivatives of the equation to obtain the total impact.

Lastly, it is imperative to keep in mind that the interpretation of interactive regressions would be based on net effects (Brambor et al., 2006) and conditional marginal impact (Asongu & Nwachukwu, 2016) in order to avoid some pitfalls that may affect the reliability of our estimations. This is especially important when considering the use of interactive regressions in our estimation technique. For the purpose of computing the net effect, it is necessary for the coefficients of the conditional and unconditional (interaction) effects to be statistically significant (Asongu & Nwachukwu, 2016, Sakariyahu et al., 2023). The net effect is computed as: ([coefficient of conditional effect * mean value of interaction variable] + coefficient of unconditional effect). Moreover, to fully understand the influence of energy poverty on the relationship between fintech and HDI, it is also important to calculate the marginal effects. The marginal effects of fintech on access to power are derived for both the mean and different percentile values of the energy poverty variable.

4. Empirical findings

4.1. *Impact of fintech on HDI*

Based on the empirical strategy, Table 3 presents the results for the direct effect of fintech on HDI for the 3 estimation techniques discussed in Section 3. The three columns (RE, GLM and GMM) show that fintech positively affects HDI at the 1 % significance levels across the regression models. This implies that the use of financial technology increases the social and economic conditions of the populace in sub-Saharan Africa. This conforms with the findings of Gomber et al. (2017), Apiors & Suzuki (2018), and Lyons et al. (2020), who find that financial technology enhances economic growth.

Furthermore, in line with the view of Tiwari et al. (2021) that the policies on access to electricity are germane for sustainable economic growth, we evaluate the effect of access to electricity on HDI. The results shown in Table 4 reveal that the coefficient of access to electricity is positive and significant with HDI at 1 % level of significance. Hence, access to electricity is an important factor that enhances HDI. This supports the expectation that the presence of adequate electricity could be a precipitator for fintech (Sarkodie

Table 5

The interaction effect of Fintech and Access to Electricity on HDI This table reports the result of model 3 which interacts the effect of Fintech and access to electricity on HDI. Estimation is performed using Random Effect (RE), Generalised Linear Model (GLM) and Generalised Method of Moments (GMM). Coefficients are computed using standard errors robust to heteroskedasticity. Standard errors are shown in parentheses. The estimations include year and country effects. Definitions of variables and data sources are provided in Appendix. *, **, *** stand for levels of significance at 10 %, 5 % and 1 % respectively. To calculate the net effect, the coefficients of both the primary and interaction variable must be significant. The net effect of 0.9851 is calculated as ([0.0220 * 41.981] + 0.0615), where 0.0220 is the conditional coefficient of the interaction between Fintech and access to electricity variable. 41.981 is the mean value of the modulating policy variable -Access to electricity- and is constant in the equation. 0.0615 is the unconditional coefficient value of the primary variable (Fintech).

VARIABLES	(1)	(2)	(3)
	RE	GLM	GMM
L.HDI	–	–	0.4883***
			(0.1160)
Fintech * Access to Electricity	0.0220**	0.0490***	0.0305**
	(0.0080)	(0.0017)	(0.0132)
Fintech	0.0615***	0.0686***	0.0277***
	(0.0056)	(0.0104)	(0.0770)
Access to Electricity	0.0113***	0.0246***	0.0180*
	(0.0025)	(0.0011)	(0.0011)
GDP per capita	0.0800	−0.0700	0.0260***
	(0.0023)	(0.0066)	(0.0080)
Institutional Quality	0.0114***	0.0252***	0.0206
	(0.0028)	(0.0288)	(0.0291)
Inflation	0.0300	−0.0196***	−0.0100
	(0.0110)	(0.0044)	(0.0040)
Trade Openness	−0.0193	0.0750***	−0.0300
	(0.0100)	(0.0700)	(0.0600)
Population Growth	−0.0378	−0.0245	−0.0850***
	(0.0242)	(0.0267)	(0.0023)
Constant	0.4718***	0.3404***	–
	(0.0186)	(0.0111)	
Net effect	0.9851	2.1257	1.3081
Year effect	Yes	Yes	Yes
Country effect	Yes	Yes	Yes
Number of countries	43	43	43
Hansen stats	–	–	13.38 (0.415)
AR (1)	–	–	−2.55 (0.011)
AR (2)	–	–	1.32 (0.186)
Number of groups	–	–	38
Number of instruments	–	–	28

Table 6

Marginal effects (energy poverty variable).

Marginal effects	Coefficient	Standard error	P-value
Mean	0.039	0.054	0.010
Percentiles			
1 %	−0.107**	0.208	0.129
5 %	−0.231**	0.087	0.108
10 %	−0.200***	0.070	0.211
25 %	−0.095**	0.041	0.013
50 %	0.045	0.078	0.010
75 %	0.139	0.145	0.087
90 %	0.287	0.201	0.055
95 %	0.403	0.243	0.094
99 %	0.496	0.281	0.038

**p < 0.005, *** p < 0.01.

& Adams, 2020; Yermack, 2018) and thus increases living conditions of people in sub-Saharan Africa.Table 5.

Next, we examine the interactive effect of fintech and access to electricity on HDI, an approach which, hitherto, has not been addressed in the literature. We find that the joint effect of fintech and access to electricity is positively significant. This implies that 1 % increase in the interaction term will lead to an increase in the level of HDI. With regards to the net effect of the interaction term, the

Table 7
GLM results using income classification of countries. This table presents the GLM regression results for the nexus between Fintech, Access to Electricity and HDI based on income classification of countries. Coefficients are computed using standard errors robust to heteroskedasticity. Standard errors are shown in parentheses. The estimations include year and country effects. Definitions of variables and data sources are provided in Appendix. *, **, *** stand for levels of significance at 10%, 5% and 1% respectively. To calculate the net effect, the coefficients of both the primary and interaction variable must be significant.

VARIABLES	LOW	LOW-MIDDLE	UPPER-MIDDLE	HIGH
Fintech * Access to Electricity	0.0148**	0.0530*	0.0900**	0.0551***
	(0.0074)	(0.0041)	(0.0028)	(0.0176)
Fintech	0.0918	0.0802	0.0538**	0.4815***
	(0.0183)	(0.0210)	(0.0226)	(0.0734)
Access to Electricity	0.0215***	0.0136***	0.0207***	−0.0229***
	(0.0034)	(0.0017)	(0.0015)	(0.0057)
GDP per capita	0.0103	0.0117	0.0600	0.0620***
	(0.0113)	(0.0094)	(0.0011)	(0.0020)
Institutional Quality	0.0287***	0.0997***	0.0463***	0.0297***
	(0.0057)	(0.0038)	(0.0080)	(0.0090)
Inflation	−0.0227***	−0.0170***	0.0115	−0.0230
	(0.0061)	(0.0055)	(0.0097)	(0.0002)
Trade Openness	0.0190	0.0440***	0.0720***	−0.0284***
	(0.0023)	(0.0012)	(0.0011)	(0.0078)
Population Growth	−0.0249***	0.0417	0.0181**	−0.0154***
	(0.0076)	(0.0446)	(0.0074)	(0.0045)
Constant	0.4372***	0.3993***	0.3598***	0.6074***
	(0.0261)	(0.0214)	(0.0362)	(0.0206)
Net effect	0.7131	–	–	2.7947

Table 8
GLM results using regional classification of countries. This table presents the GLM regression results for the nexus between Fintech, Access to Electricity and HDI on regional classification of countries. Coefficients are computed using standard errors robust to heteroskedasticity. Standard errors are shown in parentheses. The estimations include year and country effects. Definitions of variables and data sources are provided in Appendix. *, **, *** stand for levels of significance at 10%, 5% and 1% respectively. To calculate the net effect, the coefficients of both the primary and interaction variable must be significant.

VARIABLES	(1)	(2)	(3)	(4)
	WESTERN	SOUTHERN	EASTERN	CENTRAL
Fintech * Access to Electricity	0.0450**	0.0270*	−0.0130**	−0.0280*
	(0.0022)	(0.0002)	(0.0019)	(0.0064)
Fintech	0.0603	0.1049***	0.0254*	0.0239*
	(0.0106)	(0.0200)	(0.0136)	(0.0466)
Access to Electricity	0.0168***	−0.0200	0.0284***	0.0251***
	(0.0016)	(0.0032)	(0.0013)	(0.0029)
GDP per capita	0.0340	0.0350	0.0280***	0.0650
	(0.0065)	(0.0059)	(0.0106)	(0.0110)
Institutional Quality	0.0136	0.0772***	0.0305***	0.0507***
	(0.0355)	(0.0435)	(0.0031)	(0.0129)
Inflation	−0.0290***	−0.0106	0.0190	−0.00257***
	(0.0046)	(0.0076)	(0.0045)	(0.0098)
Trade Openness	0.0870***	−0.0410**	0.0250***	0.0180***
	(0.0012)	(0.0020)	(0.0090)	(0.0026)
Population Growth	−0.0453***	−0.0911	0.0514	−0.0225***
	(0.0617)	(0.0714)	(0.0405)	(0.0852)
Constant	0.4521***	0.5562***	0.4016***	0.3577***
	(0.0257)	(0.03743)	(0.0166)	(0.0231)
Net effect	1.949	–	–	–

result shows a positive significant effect for the three models. This suggests that the interactive variables would have a combined significant long-term marginal positive impact on HDI in Africa.[1] In terms of policy, this implies that access to electricity, as a key enabler of fintech, would accelerate the level of human development in sub-Saharan Africa. This corroborates the views of Sarkodie and Adams (2020) and Yermack (2018) whose separate studies also suggest that constant electricity supply would encourage the use of fintech among economic units.

Consistent with other studies (such as Mbiti & Weil, 2015; Johnson, 2016; Minto-Coy and McNaughton, 2016; Yermack, 2018), the

[1] The net effect shown in column 1 of Table 5 is 0.9851. Please see the notes under Table 5 for the calculations. To calculate the net effect, the coefficients of both the primary and interaction variable must be significant.

Table 9

Accounting for heterogeneity using MM-Quantile regression. This table presents the regression results for the nexus between Fintech, Access to Electricity and HDI. Estimation is performed using MM-Quantile regression. Coefficients are computed using standard errors robust to heteroskedasticity. Standard errors are shown in parentheses. The estimations include year and country effects. Definitions of variables and data sources are provided in Appendix. *, **, *** stand for levels of significance at 10%, 5% and 1% respectively. To calculate the net effect, the coefficients of both the primary and interaction variable must be significant.

VARIABLES	Location	Scale	Q (25)	Q (50)	Q (75)	Q (90)
Fintech * Access to Electricity	0.0490***	−0.0700	0.0570***	0.0490***	0.0420**	0.0390
	(0.0170)	(0.0900)	(0.0160)	(0.0170)	(0.0210)	(0.0250)
Fintech	0.0648***	0.0106	0.0638***	0.0649***	0.0658***	0.0664***
	(0.0115)	(0.0498)	(0.0114)	(0.0116)	(0.0134)	(0.0150)
Access to Electricity	0.0245***	−0.0330***	0.0279***	0.0240***	0.0213***	0.0196***
	(0.0011)	(0.0500)	(0.0120)	(0.0012)	(0.0012)	(0.0013)
GDP per capita	0.0740	0.0730**	0.0149**	0.0710	0.0600	0.0320
	(0.0066)	(0.0036)	(0.0073)	(0.0067)	(0.0077)	(0.0087)
Institutional Quality	0.0259***	0.0399***	0.0218***	0.0261***	0.0297***	0.0318***
	(0.0272)	(0.0126)	(0.0272)	(0.0278)	(0.0032)	(0.0036)
Inflation	−0.0209***	0.0170	−0.0226***	−0.0208***	−0.0193***	−0.0184***
	(0.0044)	(0.0019)	(0.0057)	(0.0043)	(0.0037)	(0.0037)
Trade Openness	0.0760***	0.0700*	0.0690***	0.0770***	0.0830***	0.0870***
	(0.0070)	(0.0040)	(0.0080)	(0.0070)	(0.0080)	(0.0090)
Population Growth	−0.0231	0.0307**	−0.0547*	−0.0218	0.0570	0.0218
	(0.0026)	(0.0124)	(0.0303)	(0.0027)	(0.0287)	(0.0032)
Constant	0.3416***	0.0432***	0.2972***	0.3434***	0.3821***	0.40473***
	(0.0116)	(0.0054)	(0.0124)	(0.0120)	(0.0128)	(0.0139)
Net effect	2.1219	–	3.242	2.1220	1.8290	–
Number of countries	43	43	43	43	43	43

estimated coefficients of the control variables across the models show that GDP per capita, institutional quality and trade openness are positive and significantly increase HDI. Thus, they play significant roles in augmenting the socio-economic conditions of countries. Moreover, population growth is negative and significant, suggesting an increase in population without adequate policies in place could reduce the socio-economic wellbeing of the people.

In order to assess the influence of access to electricity more accurately on the relationship between fintech and HDI, it is imperative to also calculate the marginal impacts. In this study, we focus on assessing the marginal impact of financial technology (fintech) on the HDI at both the average level and different percentiles of access to electricity. Table 6 presents the estimates of the marginal effects, together with their corresponding degrees of significance. The calculated coefficients indicate that the impact of fintech on the HDI, when assessed at the average level of access to electricity, is statistically significant. This observation suggests that the utilisation of fintech contributes to the enhancement of the HDI in nations characterised by moderate levels of electricity accessibility. The analysis reveals that the impact of fintech on HDI is negative and not significant for access to power levels, up to the 25th percentile. However, significant and positive marginal effects are observed for the higher percentiles of access to electricity. Based on our analysis, it can be inferred that in situations where access to electricity is limited, the potential for fintech tools to enhance HDI is minimal. Consequently, this creates a significant gap that might potentially be addressed by the implementation of fintech solutions. On the contrary, a higher level of access to electricity may potentially facilitate a greater scope for fintech to enhance socioeconomic circumstances. Therefore, the significance of fintech in enhancing HDI is particularly pertinent in affluent nations characterised by substantial access to electricity.

4.2. Moderating the effect of fintech and access to electricity based on income and regional classification of countries in SSA

To address the heterogeneity of the sample characteristics, we assess the influence of fintech on HDI using the regions and income-classifications of countries in sub-Saharan Africa and report the outcomes in tables 7 and 8.(See Table 9).

4.2.1. Heterogeneity by income classification of countries

In Table 7, we investigate whether the increasing impact of the interactive term (between fintech and access to electricity) on HDI varies across income levels. This income classification is based on the World Bank categorization of countries in sub-Saharan Africa. Although we establish a positive relationship between fintech and HDI across the income class, however, the result is not significant for the low-middle and low-income countries. When the interactive effect of fintech and access to electricity on HDI is checked, the result is significant for all income classifications, thus suggesting the essential role access to electricity plays in the relationship between fintech and HDI. This also conforms with the assertion of Bloom et al. (2010), that countries with high prevalence of energy poverty such as the lower income countries, may not be able to harness the gains of fintech compared to their counterparts with higher income levels. Invariably, financial technology, as a growth opportunity, tends to increase the social and economic well-being in an environment of affordable and available energy supplies.

Appendix 1
Definition of variables.

Variable	Measurement	Source of data
HDI	Human development index, computed by World Bank based on social and economic dimensions	World Development Indicators; United Nations Development Programme
Fintech index	This index is constructed using MPAY which is the proportion of adults using mobile money to pay bills; MSTORE. the proportion of adults who store money using mobile money account and MACCT which is the proportion of adults who have active mobile accounts to pay, receive or send money	Financial inclusion Indices database (Findex)
Access to electricity	The percentage of population with access to electricity	World Development Indicators
GDP per capita	A measure of a country's economic activity per person	World Development Indicators
Institutional quality index	This index is constructed using control of corruption, government effectiveness, political stability and absence of violence, rule of law, voice and accountability and regulatory quality	World Governance Indicators
Inflation	Annual percentage change in consumer prices	World Development Indicators
Trade openness	Trade openness as a percentage of GDP	World Development Indicators
Population growth	Log of the population	World Development Indicators

Appendix 2
Hausman specification test.

	Coefficient
Chi-square test value	7.105
P-value	0.119

Note. This table reports the result of Hausman specification test for fixed and random effect regression.
Decision rules- H0. Random effect is appropriate; H1. Fixed effect is appropriate.

Appendix 3
Tests for cross-sectional dependence.

	Coefficient	P-value
Pesaran's test of cross-sectional independence	−0.148	0.257
Friedman's test of cross-sectional independence	4.309	0.552

Appendix 4
Test for first order serial correlation.

	Coefficient	P-value
Wooldridge test for autocorrelation F (1,42)	10.254	0.006

Appendix 5
Wald test for heteroscedasticity.

	Coefficient	P-value
Wald test (X^2) (43)	367.20	0.0000

4.2.2. Heterogeneity by regional classification of countries

Next, Table 8 reports the results of examining whether the effect of the interactive term (between fintech and access to electricity) on HDI differs meaningfully by regions of sub-Saharan Africa. Similar to the income classifications, we find that the increasing effects of the interactive term on HDI are pronounced across regions. However, when fintech alone is regressed on HDI, output shows significant impact for only Eastern, Central and Southern regions. We imply from this result that countries in the Western region would enjoy enormous socioeconomic advancements with the adoption of fintech (Bloom et al., 2010). The current low electrification rates in the Western region act as a major barrier to the adoption and use of fintech (Yermack, 2018; Michael, 2016). Invariably, the electricity obstacle faced by most countries in the region could best explain the insignificant effect.

Finally, we employ a non-linear regression technique (the MM-quantile regression), as a check on our baseline models. This is used to explain the conditional quantiles of HDI as a function of fintech and other predictors. Thus, we divide HDI into 0.25, 0.50, 0.75 and 0.90 quantiles. As predicted, the models in Table 8 generate significant positive median coefficients for our variables of interest (fintech, access to electricity and their interaction term) and the control variables across all quantiles of the HDI. Thus, these suggest

Appendix 6
List of African countries in the sample.

S/No	Country	Regional classification	Income classification
1	Angola	Central	Low-middle income
2	Benin	Western	Low-middle income
3	Botswana	Southern	Upper-middle income
4	Burkina Faso	Western	Low-middle income
5	Burundi	Eastern	Low-income
6	Cabo Verde	Western	Low-middle income
7	Cameroon	Central	Low-middle income
8	Chad	Central	Low- income
9	Comoros	Eastern	Low-middle income
10	Cote d'Ivoire	Western	Low-middle income
11	Equatorial Guinea	Central	Upper-middle income
12	Eritrea	Eastern	Low-income
13	Eswatini	Southern	Low-middle income
14	Ethiopia	Eastern	Low-income
15	Gabon	Central	Upper-middle income
16	Gambia	Western	Low-income
17	Ghana	Western	Low-middle income
18	Guinea	Western	Upper-middle income
19	Guinea-Bissau	Western	Low-income
20	Kenya	Eastern	Low-middle income
21	Lesotho	Southern	Low-middle income
22	Liberia	Western	Low-income
23	Madagascar	Eastern	Low-income
24	Malawi	Eastern	Low-income
25	Mali	Western	Low-income
26	Mauritania	Western	Low-middle income
27	Mauritius	Eastern	Upper-middle income
28	Mozambique	Eastern	Upper-middle income
29	Namibia	Southern	Upper-middle income
30	Niger	Western	Low-income
31	Nigeria	Western	Low-middle income
32	Rwanda	Eastern	Low-income
33	Senegal	Western	Low-middle income
34	Seychelles	Eastern	High-income
35	Sierra Leone	Western	Low-income
36	Somalia	Western	Low-income
37	South Africa	Southern	Upper-middle income
38	South Sudan	Eastern	Low-income
39	Tanzania	Eastern	Low-middle income
40	Togo	Western	Low-income
41	Uganda	Eastern	Low-income
42	Zambia	Eastern	Low-income
43	Zimbabwe	Eastern	Low-middle income

that the use of financial technology drives the social and economic wellbeing of the economic units. Besides, the availability of electricity is a stimulus for fintech in enhancing high socio-economic status. The results further give support to our baseline regression outcomes.

Interestingly, while the results vary at quantile levels, they tend to increase at higher levels but reduce at lower levels. It is important to note that countries with HDI percentile below 0.50 fall into the lower income category, while above 0.50 are higher income countries. This further provides support to the findings in Table 7, that the low-middle and low income countries are less likely to appropriate the potential benefits inherent in the adoption of fintech as a growth opportunity, and may, therefore, not improve the socio-economic conditions of their economic units because of energy poverty. Overall, fintech and more importantly, the proposed moderating factor, access to electricity, are essential mechanisms that could accelerate levels of human development in sub-Saharan Africa. Indeed, our findings resonate the importance of access to electricity as a good policy variable in explaining the effects of fintech on HDI. This corroborates the assertion of Bloom et al. (2010) that countries with stable energy supply are more likely to exploit the gains of fintech and thus improve the socio-economic conditions of their citizens.

5. Conclusion

The availability and accessibility of fintech tools have been identified as one of several factors that can help improve human development. However, fintech adoption is heavily reliant on the existence of a constant electricity supply. Noting that access to electricity is a challenge in some regions of sub-Saharan Africa, this study examines the modulating impact of energy poverty on the relationship between fintech and HDI. Using robust regression techniques, our findings demonstrate that constant access to electricity is a necessity.

Policy wise, it is important for countries in the Western region as well as low- and middle-income sub-Saharan African countries to put in place measures and infrastructures that would address the energy poverty being experienced by their populace. This action would ensure that they do not miss out on the benefits of fintech adoption and at the same time, do not suffer a lag in HDI. For future studies, we urge them to explore additional proxies of fintech and energy poverty and investigate the impact of these relationships on HDI in other parts of the world, as this would establish the accuracy and consistency of our findings in a new setting.

CRediT authorship contribution statement

Fatima Oyebola Etudaiye-Muhtar: Conceptualization, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Sofia Johan:** Project administration, Supervision, Writing – original draft. **Rodiat Lawal:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. **Rilwan Sakariyahu:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendices.

(See Appendices 1 and 6).

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