Heterogeneous Effects of Frontier Technology Readiness on Economic Growth in Africa

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Abstract

Despite the remarkable growth in frontier technology adoption (FTR) in the Global South, empirical evidence concerning their socioeconomic impacts in the context of Africa is hard to find. This study, therefore, employs macro data for a sample of 39 African countries to bridge three pressing gaps in the growth literature. First, we examine the impact of FTR on economic growth. Second, the study assesses whether FTR and egalitarian democracy synergistically enhance economic growth. Third, this study examines the heterogeneous effects of FTR across growth quantiles. Robust evidence, based on the dynamic system-GMM and the method of moments quantile regression, reveals the following: first, FTR promotes economic growth, but the effect is modest; second, egalitarian democracy amplifies the growth-enhancing impact of FTR, but only at higher thresholds of egalitarianism. Third, although FTR is growth-enhancing across all growth quantiles, the effect diminishes from the 1st to the 9th quantile. However, in the presence of egalitarian democracy, FTR significantly enhances growth across all growth quantiles from the 1st to the 9th. We conclude that progress in egalitarian democracy and investments for enhancing FTR are crucial for economic growth in Africa.

Keywords: Africa; Economic growth; Democracy; Egalitarian democracy; Frontier technology readiness

JEL Codes: O31; O38; O55; Q01; P48

1. Introduction

At the heart of a sustainable, inclusive, and prosperous society is innovation (Schumpeter, 1942; Soete & Freeman, 2012; Aghion & Howitt, 1998). The innovation-growth link originates from the seminal work of Schumpeter (1911), which recognizes the critical role of entrepreneurial activities in economic growth. Subsequent contributions in this direction, for example, the endogenous growth (Aghion et al., 1998; Romer, 1986) and neo-classical growth (Solow, 1956) theories have also underscored the remarkable contribution of technological innovation to industrial productivity and average income. It is against this background that this study revisits the technological progress-growth discourse by exploring how frontier technology readiness (FTR) (used interchangeably with frontier technology adoption) impacts economic growth in Africa.

Our attention on FTR stems from the debate linking the fragile growth and generally low income of African countries to their failure to keep pace with previous industrial revolutions (see, e.g., Signé & Johnson, 2018; Collier & Gunning, 1999).[1] Indeed, lessons from previous technological waves suggest that early adopters and adapters diversify their economies for significant gains in global value chain participation, growth, and employment. As African countries seek to build resilient and inclusive growth trajectories in line with its Agenda 2063, a new window of opportunity has opened.[2] This window represents the current surge in frontier technologies, which is transforming economies, particularly sectors such as agriculture, healthcare, construction, finance, transportation, and manufacturing (UNCTAD, 2023a).[3]

Research has shown that FTR promotes industrialization, growth and descent jobs through production efficiency and competition (Graetz & Michaels, 2018; Alderucci et al., 2020). In healthcare, for instance, drones are being used to deliver medical supplies, blood, and vaccines to remote and inaccessible communities, whereas 3D printing are providing precise anatomies of patients (Umlauf & Burchardt, 2022; Ayamga et al., 2021).[4] Also, the role of the Internet of Things and generative AI in creating new entrepreneurs, products, and markets through enhanced information flow, collaboration, training, and imitation

[1]First industrial revolution (1760-1840); Second revolution (1850-1910); Third digital revolution (1960-2000).
[2]The Agenda seeks to build the industrial and institutional capacity of the continent, enhance the quality of life and ensure that by 2063, Africa becomes a key global play (African Union Commission, 2015).
[3]Examples of frontier technologies are the Internet of Things (IoT), blockchain, artificial intelligence (AI), big data, drones, robotics, quantum computing, 3D printing, nanotechnologies, organoids, genetic engineering (UNCTAD, 2023a).
[4]An example is the Zipline drone delivery service in Ghana and Rwanda (Umlauf & Burchardt, 2022).

cannot be overemphasized (Krotov, 2017; Link & Siegel, 2007). Furthermore, blockchain and machine learning algorithms are being employed in the financial system to enhance risk management, efficiency, security, and stability (Jovanovic et al., 2024; Gao & Su, 2020). Similarly, in the agricultural sector, robots and drones are being utilized for accurate spraying of pesticides and fertilizers, reducing waste and environmental impact while improving crop production (Puri et al., 2017). However, in Africa, where regulatory frameworks and digital infrastructure are least developed, and financial exclusion remains a major roadblock to open innovation and entrepreneurship, frontier technology adoption and their expected growth-enhancing effect could prove elusive.

It is in this sense we argue that the effectiveness of FTR in spurring growth in Africa could be contingent on the depth of egalitarian democracy. Our main argument is that the policies and investments of governments determine the extent to which economic agents freely and effectively leverage frontier technologies in value chains. This argument is consistent with the inclusive political institutions theory, which suggests that countries that adhere to the tenets of egalitarianism – equality in access to resources, protection of rights and freedoms of people across all social groups, and equality in access to political power – grow faster and resilient (Acemoglu & Robinson, 2012; North, 1990). Notably, Acemoglu and Robinson (2012) argue that countries fail to develop because their political elites are despotic, short-sighted, and corrupt officials who fail to plan and/or embrace incentives such as technological waves for more robust and inclusive growth.

In low-income societies such as Africa, egalitarian democracy can facilitate frontier technology deployment and new business ventures by safeguarding property rights, reducing barriers to entry for new firms, and enhancing public service delivery (see, e.g., Sigman & Lindberg, 2019; Rodrik et al., 2004; Barro, 1996). Also, in societies with more robust egalitarian democracy, governments support businesses financially and technically in adopting, mastering, and adapting frontier technologies for efficiency and sustainability (Coppedge et al., 2016; Collier & Gunning, 1999). Further, in egalitarian democracies, governments invest in quality education, training, healthcare, and research and development (R&D) to enable their economic agents, irrespective of socioeconomic background, to develop the skillset and ingenuity required for deploying and adapting frontier technologies (Acemoglu et al. 2015; Noman & Stiglitz, 2012).

Despite the rapidly evolving landscape of FTR in the Global South in the past decade (UNCTAD, 2023a), empirical evidence concerning their economic impacts in the context of Africa are hard to find. Additionally, the growth literature is mute on whether egalitarian democracy moderates FTR to promote growth in Africa. Further, to the best of our knowledge, no study has explored the conditional impact of FTR across different quantiles of growth in Africa. This study fills these gaps in the extant scholarship by responding to three questions:

1. What is the impact of FTR on economic growth?
2. Does egalitarian democracy moderate FTR to promote economic growth?
3. What is the joint effect of FTR and egalitarian democracy across growth quantiles?

Robust evidence, based on macro data from 39 African countries from 2010-2020, reveals the following: first, FTR promotes economic growth; second, egalitarian democracy amplifies the growth-enhancing effect of FTR, but only at higher thresholds of egalitarianism; and (iii) in the presence of egalitarian democracy, FTR consistently spurs growth from lower to higher quantiles. This research builds on previous studies that assess the effects of product innovation (Avenyo et al., 2019), R&D (Anakpo & Oyenubi, 2022), financial innovation (Bara et al., 2016), patenting (Gyedu et al., 2021), and digital innovation (Roger et al., 2022) on economic/inclusive growth in Africa but fail to explore the heterogenous impact of FTR on growth. Policy-wise, this study has established that egalitarian democracy is a critical complementary mechanism that conditions FTR to spur growth in Africa.

The remainder of the study is structured as follows: Section 2 provides the theoretical relationship between technological innovation and economic growth; Section 3 presents the data and methods employed for the empirical analysis; Section 4 discusses the findings; and Section 5 concludes with some policy recommendations.

2.0 Literature review

2.1 The link between frontier technology adoption and economic growth

The theoretical foundation for understanding the relationship between frontier technologies and economic growth builds upon endogenous growth and Schumpeterian

growth theories (see Schumpeter 1942, 1934, 1911). Unlike the neoclassical growth theories, which treat technological progress as exogenous, endogenous growth theories internalize technological advancement as an integral part of the growth process. Accordingly, a fundamental assumption underlying these theories is that human capital, knowledge accumulation, and technological advancement can drive sustained economic growth by increasing returns to scale and enhancing the overall productivity of various sectors of the economy (Romer, 1990; Lucas, 1988; Aghion et al., 1998). Consistent with this argument, the Schumpeterian perspective posits that frontier technologies, characterized by their novelty, transformative potential, creativity, and destructive forces, can be critical to entrepreneurship, private sector growth and economic development (Schumpeter, 1942).

The recent confluence of frontier technologies is reshaping the landscape of various economic sectors, fostering innovation, sustainability, and efficiency (UNCTAD, 2023a). To this end, embracing these advancements is widely expected to present unparalleled opportunities for businesses, governments, and society at large. For instance, among others, AI and the IoT provide a network of interconnected devices, offering real-time data and communication. Drones provide vivid aerial views, revolutionizing sectors such as agriculture, where they optimize crop monitoring. In logistics, drones facilitate faster and more cost-effective delivery services. Search and rescue operations benefit from drones' ability to access hard-to-reach areas, saving lives in emergencies. Moreover, solar PV technology is a cornerstone of renewable energy, contributing to sustainable development (International Energy Agency, 2022; Yerudkar et al., 2024).

2.2 The democracy and economic growth nexus

Over the 20th and 21st centuries, there has been widespread acceptance and implementation of democratic values and principles. The collapse of authoritarian regimes, coupled with international efforts to promote democracy, has led to an increase in the number of democracies worldwide (Diamond, 2008; Coppedge et al., 2011). However, variations persist in the extent to which countries embrace democratic governance, with diverse models and challenges shaping the landscape. In recent times, authoritarian regimes, such as those seen in China and some Sub-Sahara Africa and Middle Eastern countries, argue for stability and efficiency as reasons to avoid delays in policy

implementations and the perceived chaos that can accompany democratic transitions (Naughton, 2008).

In political economy literature, the impact of democracy on growth has been one of the most debated subjects from theoretical and empirical standpoints. Proponents of modernization theory (e.g., Lipset, 1959 and Inglehart, 1997) argue that democracy is crucial to economic growth and development because it fosters political stability, protects property rights, and promotes entrepreneurship (Barro, 1996; Rodrik et al., 2004). In support of this argument, institutional theories suggest that strong democratic institutions, such as the rule of law and property rights protection, boost investor confidence and facilitate efficient resource allocation (Acemoglu et al., 2005; North, 1990). This claim has been empirically supported by a recent by Colagrossi et al. (2020), who used a meta-analytical approach to survey 188 studies (2047 models) covering 36 years and find a direct positive growth effect of democracy. Acemoglu et al. (2014) also finds evidence of a positive growth effect of democracy.

However, Acemoglu and Robinson (2008) caution against a direct causal link between democracy and growth, emphasizing that the establishment of democratic institutions per se does not automatically guarantee their effectiveness and hence economic growth (Haggard & Tiede, 2011). Studies have shown that the democracy-growth nexus may be influenced by underlying factors such as historical legacies, cultural norms, and institutional quality. For instance, Doucouliagos and Ulubaşoğlu (2008) used meta-regression analysis to show that democracy indirectly promotes economic growth through higher human capital, lower inflation, lower political instability, and higher economic freedom. This result is corroborated by Acemoglu et al. (2014). In a study of 17 MENA countries, Nosier and El-Karamani (2018) also find that democracy positively impacts economic growth through improved health but negatively affects growth through government size and trade openness, especially in less democratic countries. In contrast, studies such as Jacob and Osang (2020) report no statistical evidence about the direct effect of democracy on economic growth. This result is confirmed by the empirical research of Khodaverdian (2022), who finds that democracy does not promote growth in Africa.

2.2 Democracy as a catalyst for frontier technologies adoption

There has been a growing body of literature that highlights some downsides of frontier technologies adoption (especially AI) (see, e.g., Acemoglu, 2021; Siddarth et al., 2021). Digital divide and disparities in access to technology and frontier technologies, for that matter, may exacerbate economic inequality, limiting the inclusive benefits of technological advancements (Njangang et al., 2022). Further, according to Acemoglu (2021), unrestricted AI use might undermine consumer choice, privacy, and competitiveness, thus resulting in increased automation, inequality, and decreased productivity. Therefore, the advancement of frontier technologies is heavily reliant on the quality of their governance and regulation, as this has a substantial impact on whether they contribute to or hinder economic progress.

Evolutionary institutional theories propose that institutions, such as political systems like democracy, have a significant impact on the preparedness of a society to embrace and adjust to new technology (Nelson, 1985; North, 1990). Research indicates that democratic systems tend to distribute resources fairly and give importance to investing in education, infrastructure, and research. These investments are crucial for fostering technological readiness and promoting equitable economic growth (Przeworski, 2000; Acemoglu et al., 2015). Additionally, inclusive democratic institutions provide opportunities for marginalized groups to participate in the economy, fostering innovation and entrepreneurship among a broader segment of the population. Furthermore, democratic governance ensures transparency, accountability, and citizen participation, which promotes public-private sector partnership, research and development, and open innovation (Diamond, 2015). Particularly, in egalitarian democracies, the pluralistic nature of decision-making, open discourse and inclusivity allow for the cross-pollination of creative ideas and the free exchange of opinions that can enhance technological progress and economic growth (Dahl, 1998; Acemoglu & Robinson, 2012; Block & Keller, 2015).

Contextually, the United States epitomizes how advanced democracies drive technological innovation. Indeed, anecdotal evidence shows that democratic principles, such as free-market competition, intellectual property protection, and a conducive regulatory framework, have propelled tech giants like Apple, Google, and Facebook to blossom. This suggests that democracy can create a conducive ecosystem that can spur frontier technological adoption and economic growth. There is also some evidence that

even in less-democratic regions, there is the promise of technological adoption. Rwanda's post-genocide democratic transition highlights the potential for democracies in Africa to bypass technological barriers and embrace innovation (Crawford & Ostrom, 1995; Akinyemi et al., 2018). Government initiatives, such as the SMART Rwanda Master Plan, mobile banking, and e-governance, showcase a commitment to harnessing frontier technologies for economic development. This development demonstrates that democratic transition can accelerate frontier technology adoption and adaption.

However, by examining the extant scholarship concerning the effects of frontier technologies on macroeconomic outcomes, we find that at least three pressing unanswered questions motivated our study. Foremost, studies have not explored the impact of frontier technology adoption on economic growth in Africa. Second, policymakers and academics alike are unaware of whether democracy is a significant transmission channel through which frontier technology adoption promotes economic growth in Africa. Third, whether the conditional effects of FTR on economic growth reduce/increase across different quantiles remains unexamined. This study bridges these gaps based on the methodology discussed in the next section.

3. The data and methodology

3.1 Data

This study employs a balanced panel for a sample of 39 African countries for the period 2010-2020 to explore the heterogeneous effects of FTR on economic growth. Table A.1 presents a list of the sampled countries. The dataset is entirely macro and is sourced from a variety of sources, namely the World Development Indicators (WDI), the Quality of Government Institute, and the United Nations Conference on Trade and Development (UNCTAD) Statistical Portal.

3.2 Dependent variable

The study employs real gross domestic product (real GDP) measured in United States dollars (2015 constant) as the dependent variable. The growth-centric literature considers Real GDP as the most appropriate measure of growth since it accounts for actual expansion in the real sector of the economy, exclusive of inflation (see, e.g., Adeleye et al., 2021). For robustness checks, we use the per capita income benchmarked in 2017 prices

as an alternative outcome variable. Per capita income is appropriate since it captures the progress in the standard of living of the population over time. Studies employing per capita income as a measure of growth also abound in the literature (see, e.g., Bara et al., 2016; Hasan & Tucci, 2010).

3.3 Main predictor

The primary independent variable in this study is frontier technology readiness. Frontier technology adoption (FTR) is an index denoting a country's preparedness and capacity in adopting and adapting Industry 4.0 technologies in its real sector. It follows that countries with high FTR are expected transform their economies for accelerated growth. FTR is an index ranging from 0 (Lowest) to 1 (Highest). According to the UNCTAD (2023a), a country's FTR score is obtained by assessing its progress across ICT deployment, R&D activity, industry activity, skills, and access to finance. The FTR series are taken from the UNCTAD Statistical Portal (UNCTAD, 2023b).

3.4 Moderating Variable

The moderating variable in this study is egalitarian democracy. Egalitarian democracy captures the extent to which (i) resources are distributed equally across all social groups, (ii) the rights and freedoms of individuals are protected equally across all social groups, and (iii) all persons enjoy equal access to power. Higher levels of egalitarian democracy are therefore expected to enhance access to frontier technologies and their effective deployment in economic systems. Egalitarian democracy is an index ranging from 0 (Lowest) to 1 (Highest). Data for egalitarian democracy are taken from the Quality of Government Institute (Coppedge et al., 2016).

3.5 Control variables

Consistent with the growth literature and the scientific procedure for generating robust multiple regression estimates, the study controls for private investment, foreign aid, political stability, electricity access and trade openness. Private is proxied by gross fixed capital formation as a percentage of GDP (Hasan & Tucci, 2010), and foreign aid is appreciated as net official development assistance a country receives from other countries as a share of gross national income (Asongu & Nwachukwu, 2016). Also, we measure trade

openness by the conventional sum of imports and exports as a share of GDP (Bara et al., 2016), whereas electricity access signifies the proportion of the total population with access to electricity (Asongu & le Roux, 2024). Political stability is an annual estimate of the perception of political stability and the absence of terrorism and violence. All the control variables are sourced from the WDI (World Bank, 2024). Tabl1 summarises the variables and their corresponding data sources.

Table 1: Description of variables and data sources

Variables	Descriptions	Sources
Dependent variables		
Economic growth	Real gross domestic product (2015 constant, US$)	World Bank (2024)
Income growth	Gross domestic product per capita in purchasing power parity terms (2017 constant, US$')	World Bank (2024)
Main predictor variables		
Frontier technology adoption	Annual frontier technology readiness index	UNCTAD (2023)
Moderating variables		
Egalitarian Democracy	Measures the extent to which (1) the rights and freedoms of people are protected, (ii) political power, and (iii) national resources are distributed equally across all social groups.	Coppedge et al. (2023)
Control variables		
Political stability	Estimate of the political stability and the absence of violence and terrorism.	World Bank (2024)
Private investment	Gross fixed capital formation as a share of gross domestic product	World Bank (2024)
Electricity access	Percentage of the population with access to electricity	World Bank (2024)
Foreign aid	Net official development assistance as a share of gross national income	World Bank (2024)
Trade openness	Total sum of imports and exports as a percentage of gross domestic product	World Bank (2024)

Source: Authors' construct, 2024

3.2 Model specification and estimation strategy

To empirically investigate the growth-effect of FTR, we follow Hasan and Tucci (2010) by specifying a dynamic panel model of the form:

$$Egrowth_{it} = \alpha_0 + \alpha_1 Egrowth_{it-1} + \beta_1 Polstab_{it} + \beta_2 Gfcf_{it} + \beta_3 Eleaccess_{it} + \beta_4 Faid_{it} + \beta_5 Trade_{it} + \beta_6 Ftr_{it} + \beta_7 Egal_{it} + \eta_i + \varphi_t + \varepsilon_{it} \quad (1)$$

To examine the conditional effect of FTR on economic growth, we modify Equation (1) by introducing an interactive term for frontier technology adoption and egalitarian democracy.

$$Egrowth_{it} = \alpha_0 + \alpha_1 Egrowth_{it-1} + \beta_1 Polstab_{it} + \beta_2 Gfcf_{it} + \beta_3 Eleaccess_{it} + \beta_4 Faid_{it} + \beta_5 Trade_{it} + \beta_6 Ftr_{it} + \beta_7 Egal_{it} + \beta_8 (Ftr_{it} \times Egal_{it}) + \eta_i + \varphi_t + \varepsilon_{it} \quad (2)$$

where $Egrowth$ is economic growth in country (i) at time (t). Similarly, we use $Polstab$ and $Gfcf$ to represent political stability and private investment, respectively. Also, $Elecaccess$ denotes electricity access, $Faid$ is foreign aid, and $Trade$ means trade openness. Likewise, FTR is frontier technology readiness/adoption, $Egal$ is egalitarian democracy and $(FTR_{it} \times Egal_{it})$ is an interactive term for frontier technology readiness and egalitarian democracy. Finally, we use η_i and ε_{it} to capture the time-invariant country-effects and the stochastic error terms, respectively.

The attendant marginal/total effect from the interplay frontier technology adoption-egalitarian democracy interaction on economic growth is estimated as:

$$\frac{\partial (Egrowth_{it})}{\partial (Ftr_{it})} = \beta_6 + \beta_8 (\overline{Egal_{it}}) \quad (3)$$

It is imperative to stress that this study assesses the conditional effect of FTR on growth at the mean and higher thresholds of egalitarian democracy. This is particularly policy-relevant to enable us to establish whether progress in egalitarian democracy above the current average is everywhere growth-enhancing.

The study estimates Equations (1) and (2) by applying the dynamic two-step system GMM estimator proposed by Kripfganz (2022). We settle on the dynamic GMM estimator

with recourse to several econometric considerations. First, Kripfganz's system GMM estimator is dynamic, meaning that it enables us to capture the effect of past growth momentum on current growth performance. Second, Kripfganz's system GMM estimator yields robust estimates when the number of entities (N) is greater than the period under consideration (T) in each cross-section. The study fulfils this requirement since N=39>T=11. Third, Kripfganz's GMM estimator addresses critical econometric issues such as endogeneity, heteroskedasticity and serial correlation that could lead to biased and inconsistent estimates.

Intuitively, serial correlation is apparent in this study because of the spatial and intertemporal linkages associated with deploying and integrating frontier technologies in countries with the same economic arrangements. This is the case since the sampled countries collectively signed onto the African Continental Free Trade Area. Also, the endogeneity concern in this study arises from the possible reverse causality between FTR and economic growth. For instance, economic growth signifies expansion in the real sector of the economy, meaning that firms/businesses have more capacity and incentive to employ frontier technologies to withstand competition and demand (UNCTAD, 2023a). On the other hand, FTR can enhance production efficiency and private sector growth, which can accelerate economic growth (Graetz, G., & Michaels, 2018). The study addresses the endogeneity problem by employing internal and external instruments. For the former, we use the first lagged difference of the outcome variable. Also, we employ the independent variables and time (the years) as external instruments, which is consistent with Roodman (2009).

That said, we assess the robustness of the GMM results against some benchmarks. First, we evaluate whether the study passes the overidentification restriction. To this end, we apply the Hansen (1982) test of over-identification. The test requires that the attendant p-values be insignificant. Second, we check for any second-order serial correlations in the residuals. This means that the test for no autocorrelation in the residuals must not be rejected. Third, we examine whether there are no issues of overfitting and instrument proliferation. Further, we assess the overall fit of models using the F-statistics test.

3.3 Method of moments quantile regression

To answer Question 3, we employ the Machado and Silva (2019) method of moment quantile regression estimator (MMQREG), which is an extension of Koenker and Bassett (1978). We choose the MMQREG for the following reasons. First, it allows us to assess the distributional and heterogeneous impact of FTR across growth quantiles. (Ike et al., 2020). In other words, the MMQREG enables us to estimate the conditional median or a variety of different growth quantiles subject to certain values of FTR. Second, the MMQREG yields robust estimates even in the presence of outliers (Machado & Silva, 2019). Third, studies by Ike et al. (2020) and Binder and Coad (2011) also confirm that the MMQREG is appropriate in cases where the conditional means of the variables of interest (i.e., FTR and economic growth) is weak or non-existent. Fourth, unlike the traditional quantile regression methods (see, e.g., Canay, 2011; Koenker, 2004), the Machado and Silva (2019) MMQREG accounts for unobserved heterogeneity across panels, allowing individual characteristics to influence the entire distribution rather than just shifting the means. Fifth, the MMQREG is designed to address endogeneity issues, yielding unbiased estimates. Following Machado and Silva (2019), we specify the MMQREG models as:

$$Q_y(\gamma/X_{it}) = \ (\varphi_i + \partial_i q(\gamma)) + h\, X'_{it}\beta + \vartheta Z'_{it} q(\gamma) \qquad (5)$$

where $Q_y(\gamma/X_{it})$ denotes the quantile distribution of the outcome variable (i.e., economic growth), conditioned on the location of the predictor variables X_{it} (i.e., FTR, political stability, private investment, electricity access, foreign aid, and trade openness). Also, $\varphi_i(\gamma) \equiv \varphi_i + \partial_i q(\gamma)$ is the scalar coefficient of the quantile - γ fixed effect for country i. It is instructive to note that these country-effects are time-invariant parameters whose heterogeneity effects are allowed to differ across quantiles of the conditional distribution of the dependent variable y. Accordingly, these time-invariant country effects do not represent an intercept shift, as it is the least-squares fixed effect estimator.

4. Presentation and discussion of results

4.1 Summary statistics and preliminary results

Table 2 reveals an average real economic growth value of US$46.8 billion for the sampled countries. Similarly, we report mean values of 0.214 and 0.289 for Frontier technology adoption and egalitarian democracy, respectively. Whereas the latter suggests glaring disparities in access to political power, economic resource ownership, and rights and freedoms across social groups in Africa, the former signifies the low capacity of the sampled countries in adopting and adapting frontier technologies.

Table 2: Summary statistics, 2010-2020

Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Economic growth	429	4.680e+10	7.646e+10	8.918e+08	4.122e+11
Income per capita	429	5667.599	5456.204	711.355	32214.906
Frontier technology adoption	429	0.214	0.137	0.000	0.600
Egalitarian Democracy	429	0.289	0.151	0.068	0.642
Political stability	429	-0.598	0.797	-2.665	1.111
Private investment	427	23.520	8.851	5.885	81.021
Foreign aid	429	5.454	5.251	0.010	31.050
Trade openness	426	67.967	27.309	0.757	149.890
Electricity access	429	50.081	27.229	5.300	100.000

Note: Obs is observations; Std. Dev. is the Standard Deviation

The data also reveals average political stability and electricity access estimates of -0.598 and 50.081, respectively. These figures highlight the fragile state of Africa's political architecture and the high number of people without electricity.

With all that said, we proceed to explore the correlation between economic growth and frontier technology readiness through graphical analysis. First, Figure 1 shows that frontier technology readiness is positively related to economic growth. Notably, Figure 1

indicates that higher levels of frontier technology adoption are associated with higher levels of economic growth.

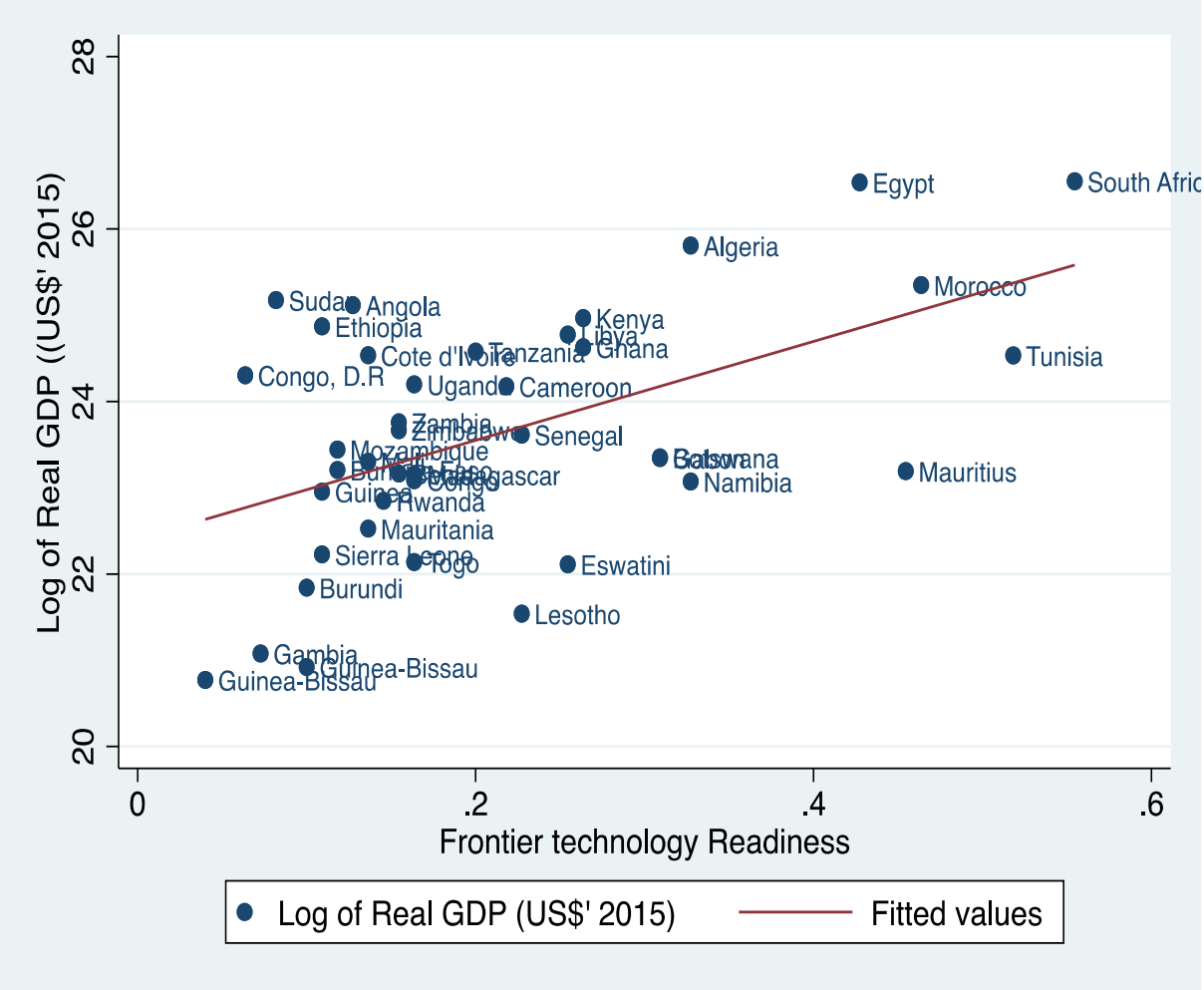

Figure 1: Relationship between frontier technology readiness and economic growth in Africa.

This positive relationship becomes notable when we explore the nexus between income growth and frontier technology readiness. Figure 2 shows that building capacity for adopting and adapting is strongly linked to higher average incomes. Notably, Figure 2 indicates a strong positive relationship between average income and countries with higher readiness for frontier technology adoption (i.e., Mauritius, South Africa, Morocco, Egypt, and Tunisia). The correlation results in Table A.2 affirm these positive relationships in Figures 1 and 2.

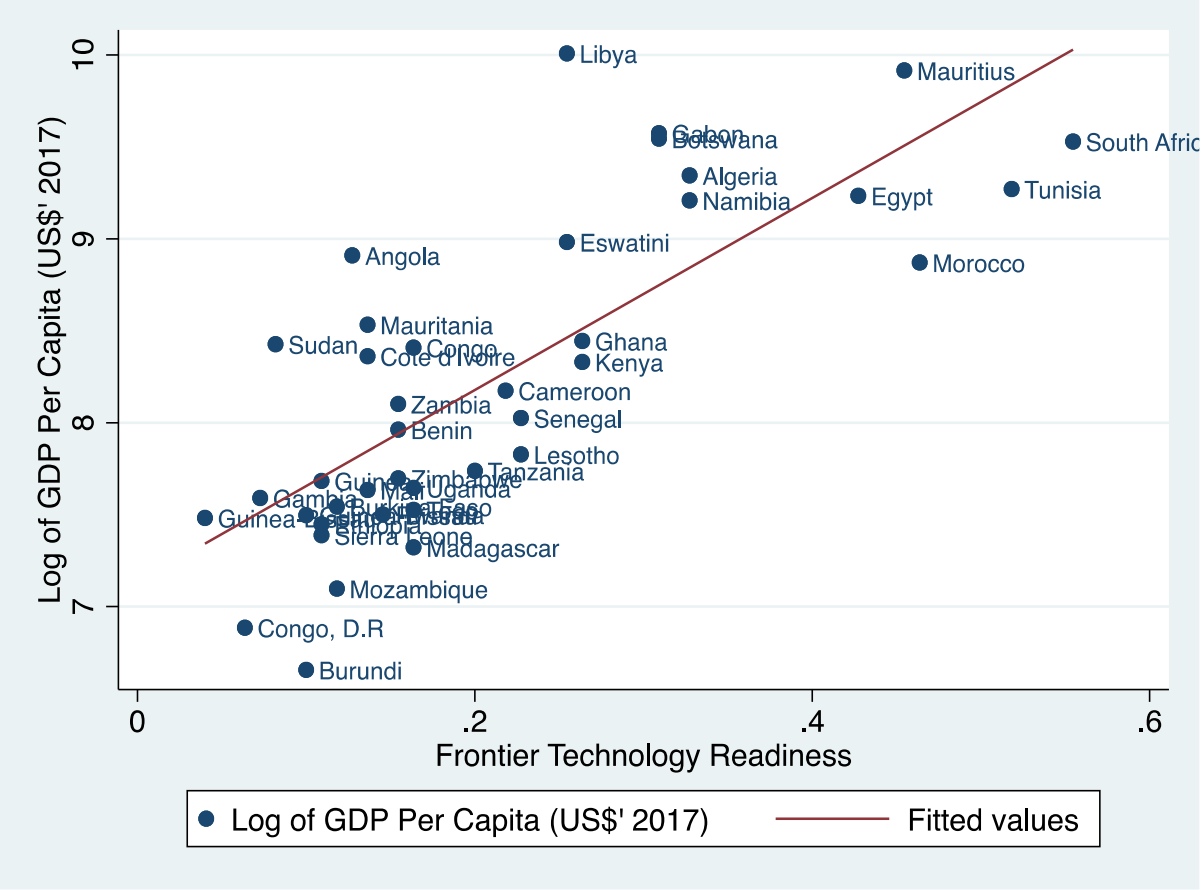

Figure 2: Relationship between frontier technology readiness and Income in Africa.

4.3 Effects of FTR and egalitarian Democracy on economic growth

Table 3 reports results from GMM estimations for the effects of frontier technologies readiness (FTR) on economic growth. Columns 1 – 3 show results from the main analysis, where the log of real GDP (in 2015 constant US$) is the dependent variable, whilst Columns 4 – 6 display findings for the robustness checks, with the log of GDP per capita as the outcome variable.

For Question 1, we find that FTR increases economic growth, albeit modest. The magnitude of the coefficient suggests that a unit increase in FTR is associated with a 0.127% rise in economic growth. This evidence is statistically significant at the 1% significance level and aligns with Brynjolfsson and McAfee (2014) that frontier technology deployment enhances productivity by automating routine tasks, thereby allowing human workers to focus on more creative and complex aspects of their jobs.

Table 3: Effects of FTR and Egalitarian Democracy of Economic Growth

	Main	**Results**		**Robustness**	**Checks**	
Variables	lgdp2015	lgdp2015	lgdp2015	lgpc2017	lgpc2017	lgpc2017
Real GDP (-1)	0.9360***	0.9502***	0.9345***	–	–	–
	(0.0218)	(0.0413)	(0.0354)	–	–	–
Income per capita (-1)	–	–	–	0.4182***	0.6457***	0.6624***
	–	–	–	(0.0441)	(0.1223)	(0.1096)
Political stability	-0.0034	-0.0051	0.0121	-0.0170***	-0.0236	-0.0042
	(0.0072)	(0.0125)	(0.0151)	(0.0063)	(0.0157)	(0.0157)
Domestic investment	-0.0009***	-0.0008*	-0.0008***	-0.0004**	-0.0005	-0.0003
	(0.0003)	(0.0004)	(0.0003)	(0.0002)	(0.0005)	(0.0006)
Foreign aid	-0.0059***	-0.0063***	-0.0048***	-0.0059***	-0.0055***	-0.0059***
	(0.0015)	(0.0013)	(0.0011)	(0.0015)	(0.0013)	(0.0013)
Trade openness	0.0017***	0.0016***	0.0013***	0.0013***	0.0007**	0.0009***
	(0.0002)	(0.0003)	(0.0003)	(0.0001)	(0.0003)	(0.0003)
Electricity access	-0.0006	-0.0012*	-0.0009	0.0024***	0.0007	-0.0001
	(0.0005)	(0.0006)	(0.0008)	(0.0005)	(0.0006)	(0.0007)
FTR	**0.1277*** **	**0.1735*** **	**-1.0880*** **	**0.1126*** **	**0.1589*** **	**-0.6357***
	(0.0299)	(0.0363)	(0.2166)	(0.0184)	(0.0422)	(0.3352)
Egalitarian Democracy		0.9768**	0.0603		1.4022***	0.6539*
		(0.3853)	(0.2270)		(0.3496)	(0.3409)
FTR x Egalitarian Democracy			**4.1872*** **			**2.5462** **
			(0.9712)			(1.2113)
Constant	1.4925***	0.8881	1.4952*	4.6048***	2.4091**	2.4989***
	(0.5072)	(0.9840)	(0.8121)	(0.3618)	(0.9938)	(0.8864)
Observations	388	388	388	388	388	388
Countries	39	39	39	39	39	39

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Further, because frontier technologies often require continuous research and development (R&D) efforts, increased R&D investment and innovation can foster the development of new products and services, creating economic value and promoting growth.

In Column 3, we provide evidence in the remit of Question 2. We find a positive and statistically significant coefficient for FTR and egalitarian democracy interaction term (4.1872), meaning that the two variables synergistically enhance growth. In other words, in the presence of egalitarian democracy, FTR significantly boosts economic growth. Statistical support for the attendant total effect, however, proves elusive. We attribute this to the low level of egalitarian democracy in the sampled countries. Notwithstanding, the positive interactive coefficient confirms our argument that egalitarian democracies prioritize inclusive decision-making, allowing for broader stakeholder consultations. For example, the state can support households and firms in acquiring and integrating frontiers in their businesses. This, in effect, can lead to the implementation of all-inclusive and technology-driven programmes for resilient growth.

For our control variables, the evidence shows that political stability hinders economic growth. Although this result is unexpected, we link it to the widespread geopolitical fragility in many African countries. Indeed, the overall political stability performance of the sampled countries is negative, as apparent in Table 2. In such contexts, political instability introduces uncertainty, adversely affecting long-term economic planning, investor confidence, supply chains and the consistent implementation of growth-oriented policies (Okafor, 2017). Also, contrary to Boamah et al.'s (2018) findings, we report a negative relationship between private investment and economic growth. We argue that the socioeconomic challenges of Africa, notably the perennial macroeconomic instability and institutional constraints (e.g., widespread corruption and repressed regulatory frameworks), impedes the potential role of investment utilization on growth. Further, we find a negative and statistically significant impact of foreign aid on economic growth. This evidence corroborates recent findings that foreign aid flows to Africa are volatile and ineffective in generating long-term growth (Tang & Bundhoo, 2017). Finally, we demonstrate that trade openness promotes economic growth, corroborating existing empirical evidence (see Chang & Mendy, 2012; Keho, 2017).

4.2.1 Effects of FTR on economic growth at various egalitarian democracy thresholds

Following our results in Table 3, we proceed to examine whether higher levels of egalitarian democracy moderate FTR to promote economic growth. Robust evidence in Table 5 reveals that improvement in egalitarian democracy from the current level of 0.28 (28%) to 0.50 (50%) or better is everywhere growth-enhancing. For instance, at an egalitarian democracy threshold of 0.50, FTR increases economic growth by 1.005%. This effect rises to 2.261% and 3.057% when egalitarian democracy improves to 0.80 and 0.99, respectively. Our result suggests that although frontier technologies spur growth, their impacts are remarkable in the presence of a more egalitarian political system.

Table 4: FTR effects at various egalitarian democracy thresholds

Egalitarian democracy thresholds	lgdp2015	lgpc2017
0.28	**0.0844**	**0.0772**
	(0.1208)	**(0.0797)**
0.50	1.0055***	0.6374**
	(0.3049)	(0.2906)
0.60	1.4243***	0.8920**
	(0.3985)	(0.4086)
0.70	1.8430***	1.1466**
	(0.4934)	(0.5280)
0.80	2.2617***	1.4012**
	(0.5890)	(0.6480)
0.90	2.6804***	1.6559**
	(0.6851)	(0.7684)
0.99	3.0573***	1.8850**
	(0.7718)	(0.8769)

Note: Standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1

4.3 Heterogenous effects of FTR on economic growth

So far, this study has established that, directly or indirectly, FTR enhances economic growth. However, it remains unclear whether this positive varies across different quantiles of growth. Accordingly, in this section, we examine the distributional effects of FTR across growth quantiles. This analysis is relevant because it enables policymakers to appreciate ex-ante the short- to long-term growth effects of investments in frontier technologies.

Table 6: Quantile regression results for the effects of FTR on economic growth (Dependent Variable: lgdp2015)

Variables	Location	Scale	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Political stability	-0.0081	0.0019	-0.0111	-0.0102	-0.0095	-0.0087	-0.0079	-0.0073	-0.0066	-0.0060	-0.0054
	(0.0367)	(0.0145)	(0.0417)	(0.0389)	(0.0374)	(0.0366)	(0.0369)	(0.0377)	(0.0394)	(0.0416)	(0.0439)
Domestic investment	0.0013	-0.0009	0.0027	0.0023	0.0020	0.0016	0.0013	0.0010	0.0007	0.0003	0.0001
	(0.0016)	(0.0006)	(0.0023)	(0.0021)	(0.0019)	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0014)	(0.0014)
Foreign aid	-0.0121***	0.0029**	-0.0168***	-0.0154***	-0.0144***	-0.0130***	-0.0119***	-0.0110***	-0.0099***	-0.0088**	-0.0079**
	(0.0040)	(0.0013)	(0.0051)	(0.0046)	(0.0044)	(0.0042)	(0.0039)	(0.0038)	(0.0038)	(0.0037)	(0.0038)
Trade openness	0.0003	0.0001	0.0001	0.0002	0.0002	0.0002	0.0003	0.0003	0.0004	0.0004	0.0004
	(0.0010)	(0.0003)	(0.0012)	(0.0011)	(0.0011)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Electricity access	0.0119***	0.0002	0.0115***	0.0116***	0.0117***	0.0118***	0.0119***	0.0120***	0.0121***	0.0122***	0.0122***
	(0.0015)	(0.0005)	(0.0019)	(0.0017)	(0.0016)	(0.0015)	(0.0015)	(0.0014)	(0.0014)	(0.0014)	(0.0014)
FTR	**0.6085*** **	**-0.0385**	**0.6708*** **	**0.6521*** **	**0.6382*** **	**0.6208*** **	**0.6052*** **	**0.5934*** **	**0.5786*** **	**0.5648*** **	**0.5526*** **
	(0.1515)	(0.0616)	(0.1933)	(0.1751)	(0.1653)	(0.1558)	(0.1511)	(0.1498)	(0.1526)	(0.1575)	(0.1645)
Constant	22.9605***	0.0677**	22.8510***	22.8838***	22.9082***	22.9389***	22.9662***	22.9869***	23.0130***	23.0371***	23.0586***
	(0.1126)	(0.0338)	(0.1467)	(0.1357)	(0.1287)	(0.1189)	(0.1120)	(0.1064)	(0.1016)	(0.0986)	(0.0980)
Observations	426	426	426	426	426	426	426	426	426	426	426

Note: FTR is Frontier Technology Readiness; Q1- Q9 denotes Quantile 1- Quantile 9; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table 7: Quantile regression results for the joint effect of FTR and egalitarian democracy on economic growth (Dependent Variable: lgdp2015)

Variables	Location	Scale	Qtile__1	Qtile__2	Qtile__3	Qtile__4	Qtile__5	Qtile__6	Qtile__7	Qtile__8	Qtile__9
Political stability	-0.0093	0.0051	-0.0173	-0.0151	-0.0129	-0.0110	-0.0087	-0.0072	-0.0055	-0.0037	-0.0018
	(0.0382)	(0.0165)	(0.0427)	(0.0400)	(0.0382)	(0.0378)	(0.0386)	(0.0398)	(0.0419)	(0.0448)	(0.0481)
Domestic investment	0.0014	-0.0009	0.0028	0.0024	0.0021	0.0017	0.0013	0.0010	0.0007	0.0004	0.0001
	(0.0016)	(0.0006)	(0.0023)	(0.0021)	(0.0019)	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0014)	(0.0013)
Foreign aid	-0.0125***	0.0030**	-0.0173***	-0.0160***	-0.0147***	-0.0135***	-0.0121***	-0.0112***	-0.0102***	-0.0091**	-0.0080**
	(0.0038)	(0.0014)	(0.0050)	(0.0046)	(0.0043)	(0.0041)	(0.0038)	(0.0037)	(0.0036)	(0.0036)	(0.0036)
Trade openness	0.0002	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003
	(0.0010)	(0.0003)	(0.0012)	(0.0011)	(0.0011)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Electricity access	0.0118***	0.0001	0.0116***	0.0116***	0.0117***	0.0117***	0.0118***	0.0118***	0.0119***	0.0119***	0.0120***
	(0.0015)	(0.0005)	(0.0019)	(0.0018)	(0.0016)	(0.0015)	(0.0014)	(0.0014)	(0.0014)	(0.0014)	(0.0014)
FTR	**0.5594****	**-0.0829**	**0.6895****	**0.6539****	**0.6181****	**0.5873****	**0.5494****	**0.5245****	**0.4965***	**0.4677***	**0.4371**
	(0.2619)	(0.1063)	(0.3458)	(0.3158)	(0.2894)	(0.2729)	(0.2592)	(0.2541)	(0.2551)	(0.2606)	(0.2694)
Egalitarian Democracy	0.2083	-0.0795	0.3330	0.2989	0.2645	0.2351	0.1988	0.1749	0.1481	0.1205	0.0911
	(0.2515)	(0.1333)	(0.3211)	(0.2882)	(0.2631)	(0.2528)	(0.2529)	(0.2602)	(0.2764)	(0.3002)	(0.3268)
FTRxEgal	**0.2083**	**0.1998**	**-0.1050**	**-0.0194**	**0.0670**	**0.1412**	**0.2324**	**0.2925**	**0.3599**	**0.4292**	**0.5031**
	(0.6300)	**(0.2886)**	**(0.8900)**	**(0.8003)**	**(0.7181)**	**(0.6646)**	**(0.6193)**	**(0.6026)**	**(0.6006)**	**(0.6154)**	**(0.6380)**
Constant	22.9044***	0.0964*	22.7532***	22.7945***	22.8362***	22.8720***	22.9160***	22.9450***	22.9775***	23.0109***	23.0466***
	(0.1270)	(0.0496)	(0.1710)	(0.1583)	(0.1437)	(0.1350)	(0.1262)	(0.1210)	(0.1189)	(0.1197)	(0.1210)
Observations	426	426	426	426	426	426	426	426	426	426	426

Note: FTR is Frontier Technology Readiness; Q1- Q9 denotes Quantile 1- Quantile 9; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The attendant findings, which are based on the method of moments quantile regression, are compelling. We show that FTR positively enhances growth across all quantiles. Several developments in Africa offer anecdotal support for this finding. For instance, the rise in innovation hubs such as Silicon Cape and JoziHub in South Africa is opening new growth poles through entrepreneurship, global value chain participation, and decent jobs (Pollio, 2020). In Kenya, the success of M-Pesa (Mobile Money) has spawned a vibrant ecosystem of fintech startups and innovation hubs, positioning Kenya as a leader in mobile money technology and driving economic growth through increased access to financial services. Similarly, the Zipline medical drone delivery service in Ghana and Rwanda is providing jobs and contributing to a healthy workforce.

However, we find a piece of evidence that could have been hidden had we not employed quantile regression analysis. This is because the growth-inducing effect of FTR is highest/remarkable at the 1st quantile. This is highlighted by the negative scale-effect of FTR on growth. Precisely, the impact of FTR on growth reduces from 0.670% at the 1st quantile to 0.552% by the 9th quantile. This is consistent with the diminishing returns/saturation effect of innovation. The uniqueness and relevance of this finding is that without complementary mechanisms, the impact of FTR is relatively negligible at higher growth quantiles.

Accordingly, we deepen the analysis by examining whether egalitarian democracy mitigates this saturation effect. The corresponding finding, which we report in Table 7, shows that egalitarian democracy is a significant complementary mechanism that conditions the FTR to promote growth. This is highlighted by the positive coefficients of the FTR-egalitarian democracy interaction terms across all quantiles. That said, we proceed to compute the associated total effects (see Table 8). We find that in the presence of egalitarian democracy, FTR instead increases economic growth from the 1st-9th quantiles. Specifically, Table 8 shows that the marginal effect of FTR on growth rises from 0.53% to 0.70%, given the mean of egalitarian democracy (0.28). This result demonstrates that egalitarian democracy is a significant complementary mechanism that mitigates the saturation effect of FTR growth.

Table 8: Conditional effects of FTR across growth quantiles (Dependent Variable: lgdp2015)

Egalitarian democracy thresholds	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
0.28	0.5300**	0.5539**	0.5781**	0.5989**	0.6244**	0.6413**	0.6601**	0.6795***	0.7002***
	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)
0.50	0.5068*	0.5497**	0.5929**	0.6299**	0.6756**	0.7056***	0.7393***	0.7740***	0.8109***
	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)
0.60	0.4963*	0.5477**	0.5996**	0.6441**	0.6988***	0.7349***	0.7753***	0.8169***	0.8612***
	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)
0.70	0.4858*	0.5458**	0.6063**	0.6582**	0.7221***	0.7641***	0.8113***	0.8598***	0.9116***
	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)	(0.2619)
0.80	0.4753*	0.5438**	0.6130**	0.6723**	0.7453***	0.7934***	0.8473***	0.9027***	0.9619***
	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)
0.90	0.4648*	0.5419**	0.6197**	0.6864***	0.7686***	0.8226***	0.8833***	0.9456***	1.0122***
	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)	(0.2169)
0.99	**0.4554***	**0.5402****	**0.6257****	**0.6991*****	**0.7895*****	**0.8490*****	**0.9157*****	**0.9843*****	**1.0575*****
	(0.2169)	**(0.2169)**	**(0.2169)**	**(0.2169)**	**(0.2169)**	**(0.2169)**	**(0.2169)**	**(0.2169)**	**(0.2169)**

Note: Q1- Q9 denotes Quantile 1- Quantile 9; Standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1

This growth-inducing conditional effect of FTR becomes notable when higher thresholds of egalitarian democracy are considered. For instance, progress in egalitarian democracy from the current average of 0.28 to 0.60 moderates FTR to increase growth from 0.506% in the 1st quantile to 0.810% in the 9th quantile. This marginal effect of FTR increases to 1.01% and 1.05% by the 9th quantile when egalitarian democracy thresholds of 0.90 and 0.99 are considered.[5]

5. Concluding remarks and policy recommendations

This study empirically examined the heterogenous effects of FTR on economic growth using macro data for a sample of 39 African countries from 2010-2020. Three questions formed the basis of this empirical scrutiny. Foremost, this study investigated the direct effect of FTR on economic growth. Second, this study assessed the moderation effect of egalitarian democracy in the FTR-growth nexus. Third, we explored the heterogeneous impact of FTR across different quantiles of growth.

Robust empirical evidence, based on the dynamics system-GMM and the methods of moments quantile regression, reveal the following: first, we find that FTR is growth-enhancing, albeit modest; second, egalitarian democracy amplifies the positive effect FTR on economic growth, but only at the higher levels of egalitarianism; third, the quantile results reveal that although FTR promotes economic growth, this effect reduces from the 1^{st}-9^{th} quantiles. However, the contingency and threshold analyses show that in the presence of egalitarian democracy, FTR spurs growth from the 1^{st} to 9^{th} quantiles.

These findings lead to the following critical recommendations. Foremost, African governments should prioritize the implementation of policies aimed at enhancing access to quality education and training programs tailored to frontier technologies. This entails initiatives targeting digital literacy, technical skills development, and vocational training, ensuring the workforce is proficient in leveraging these technologies. For example, governments could establish partnerships with tech companies to offer specialized training programs or introduce digital literacy courses in school curricula. Secondly, governments should enact targeted policies supporting innovation and entrepreneurship

[5]For brevity, the indicate that the quantile regression results with income per capita as the dependent variable will be provided upon request.

within the technology sector. This may include providing incentives for research and development, fostering public-private partnerships, and creating regulatory environments conducive to startup growth. For instance, governments could offer tax incentives for tech startups or establish innovation hubs with access to funding and mentorship. Lastly, it is crucial to promote policies that bolster inclusive democratic institutions, including transparent governance structures and equitable resource distribution. Strengthening democratic governance enhances regulatory capacity, enabling governments to facilitate the adoption of frontier technologies in a manner that fosters equitable economic growth and reduces disparities. For instance, implementing open data policies can enhance transparency and accountability while ensuring marginalized communities have a voice in decision-making processes.

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Appendices

Table A.1: List of countries

Algeria	Egypt	Libya	Sierra Leone
Angola	Eswatini	Madagascar	South Africa
Benin	Ethiopia	Mali	Sudan
Botswana	Gabon	Mauritania	Tanzania
Burkina Faso	Gambia	Mauritius	Togo
Burundi	Ghana	Morocco	Tunisia
Cameroon	Guinea	Mozambique	Uganda
Congo Republic	Guinea-Bissau	Namibia	Zambia
Congo, D.R.	Kenya	Rwanda	Zimbabwe
Cote d'Ivoire	Lesotho	Senegal	

Table A.4: Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Per capita income	1								
(2) Economic growth	0.456***	1							
(3) FTR	**0.717*** **	**0.485*** **	1						
(4) Egalitarian Democracy	0.241***	-0.0512	0.390***	1					
(5) Political stability	0.275***	-0.281***	0.274***	0.543***	1				
(6) Private investment	0.0582	0.153**	-0.0550	-0.0574	0.0771	1			
(7) Foreign aid	-0.763***	-0.536***	-0.536***	-0.110*	-0.140**	-0.174***	1		
(8) Trade openness	0.252***	-0.310***	0.173***	0.312***	0.454***	0.196***	-0.150**	1	
(9) Electricity access	0.826***	0.509***	0.796***	0.250***	0.156**	-0.0008	-0.655***	0.116*	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Conditional effects of FTR across growth quantiles (Dependent Variable: lgpc2017)

Egalitarian democracy thresholds	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
0.28	0.1867	0.1998	0.2078	0.2172	0.2278	0.2356	0.2413	0.2492	0.2592
	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)
0.50	0.3294	0.3526	0.3670	0.3836	0.4026	0.4166*	0.4267*	0.4408*	0.4588*
	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)
0.60	0.3942	0.4221*	0.4393*	0.4593*	0.4821*	0.4988**	0.5110**	0.5279**	0.5495**
	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)
0.70	0.4590*	0.4916*	0.5117**	0.5350**	0.5615**	0.5811**	0.5953**	0.6151**	0.6402**
	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)
0.80	0.5238**	0.5611**	0.5840**	0.6107**	0.6410**	0.6633***	0.6796***	0.7022***	0.7309***
	(0.6480)	(0.6480)	(0.6480)	(0.6480)	(0.6480)	(0.6480)	(0.6480)	(0.6480)	(0.6480)
0.90	0.5886**	0.6305**	0.6563***	0.6864***	0.7205***	0.7456***	0.7639***	0.7893***	0.8217***
	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)
0.99	0.6470**	0.6931***	0.7214***	0.7545***	0.7920***	0.8196***	0.8397***	0.8677***	0.9033***
	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)	(0.2515)

Note: Q1- Q9 denotes Quantile 1- Quantile 9; Standard errors in parenthesis; *** p<0.01, ** p<0.05, * p<0.1