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Institutional quality effect of ICT penetration: Global and regional perspectives

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Background: As countries at global and regional levels work towards achieving the United Nations Sustainable Development Goal (SDG) 16, which emphasises the establishment and promotion of strong and inclusive institutions, there is a growing urgency to harness the power of information and communications technology (ICT) penetration in order to accomplish this objective. Hence, the rational for this study.

Aim: The institutional quality effect of ICT penetration (ICTP) is investigated at global and regional levels.

Setting: Annual panel data for 183 countries spanning 2003–2021 are utilised. The countries were further disaggregated to five major regions.

Method: We applied the Two-Step System-Generalized Method of Moments (SGMM) estimation approach that incorporate forward orthogonal deviations to achieve the objective of the study.

Results: The results of the SGMM analysis demonstrate a statistically significant and positive effect of ICTP on institutional quality at the global level. However, the effect varies significantly at the regional level.

Conclusion: Overall, considering the inclusion of other control variables in the estimations, it is indicated that global and regional governments, as well as policymakers, could accelerate the achievement of institutional quality by strategically harnessing the potential of ICTP.

Contribution: This study makes a valuable contribution to the existing literature by revealing the impact of ICTP on institutional quality at both global and regional levels. To address endogeneity concerns, the Two-Step SGMM methodology is employed, offering a robust analytical framework for analysis.

Keywords: institutional quality; information and communications technology (ICT) penetration; two-step SGMM; panel data; regions.

Introduction

The research inquiry in this study is driven by four primary considerations: (1) the potential of information and communications technology (ICT) penetration in all sectors of the global and regional economies; (2) the challenge of achieving the Sustainable Development Goal (SDG) 16, which emphasises the establishment and promotion of strong and inclusive institutions on a global and regional scale; (3) the significant potential of ICT penetration (ICTP) to enhance institutional quality globally and regionally; and (4) the crucial need to explore these interconnections within the context of the study. Additionally, the presence of research gaps in the empirical literature on institutions necessitates attention and further investigation. Information and communications technology has revolutionised the way societies operate, transforming various sectors, including communication, commerce, education, and governance. The widespread adoption and penetration of ICT have raised important questions about its impact on institutional quality, which encompasses the effectiveness, efficiency, and integrity of institutions in a given country or region. Understanding the relationship between ICT penetration (ICTP) and institutional quality, is crucial for policymakers and researchers aiming to leverage technology for sustainable development and improved institutional performance across the global.

In a study conducted by Alonso and Garcimartín (2013) the determinants of institutional quality are investigated and revealed that factors such as development level, tax system, and income distribution positively influence institutional quality. Building upon this research, Alonso, Garcimartín and Kvedaras (2020) extended the study by exploring additional variables that might

determine institutional quality. The findings of their study affirmed that institutional quality is influenced by variables that could be shaped by public policy, including international openness, education, and others. In Entele's (2021) study, the fixed-effect panel data model is employed to examine the influence of institutions and ICT services on avoiding the resource curse in successful economies from 1995 to 2019. The findings demonstrate that some economies experience negative economic growth in fact due to abundant natural resources and institutional performance, indicating the presence of resource and institutional curses. However, overcoming these curses is possible through the development of human capital, adoption of ICT, and improvement of institutions. In recent years, different empirical studies support the institutional quality – economic development nexus. Additionally, although to a lesser extent, evidence has also suggested a connection between institutional quality and growth (Aron 2000). The positive/negative/mixed relationship between institutional quality and economic development has been highlighted in cross-country investigations in previous studies (see for example, Acemoglu, Johnson & Robinson 2002; Easterly & Levine 1997; Hall & Jones 1999; Lio, Liu & Ou 2011; Rodrik, Subramanian & Trebbi 2004; Shim & Eom 2008), panel data analyses (Henisz 2000; Shirazi 2008; Tavares & Warcziarg 2001; Varsakelis 2006) and case studies (e.g., Rodrik 2003), among others. In these studies is explored the relationship between institutional quality and economic development, or growth, considering various macroeconomic and socioeconomic variables, yielding either positive, or negative, or mixed results. Since there is a lack of comprehensive studies examining the nexus between ICT penetration (ICTP) and institutional quality at both global and regional levels, it is essential to fill this gap. This research offers a more balanced understanding on how ICT influences institutions on a global and regional scale. And such insights could help policymakers to make well-informed decisions, ultimately leading to more precisely targeted policies and strategies for international institution. Offering insights into the previously unaddressed causal relationship between global and regional ICT penetration (ICTP) and institutional , will shed light on the specific pathways through which ICT impacts institutions. Understanding these mechanisms is crucial to designing effective policies and interventions to harness the benefits of ICT for governance and institutions, thus enhancing policy recommendations and providing a deeper understanding of maximising these benefits which is expected to lead to improved and enhanced economic/social development.

To the best of our knowledge, in no previous study has the institutional quality effect of ICTP at global and regional levels been investigated. Moreover, the scope of previous studies is constrained by limitations to the study period and the number of countries examined. Furthermore, some of the methodologies employed, fail to address important aspects, such as panel data issues and robust endogeneity. This research sets itself apart from previous literature by creating a composite index for ICT, which includes three variables, as well as an index for institutional quality, derived from six governance indicators, using principal component analysis (PCA). Thus, the aim with the present analysis is to bridge these gaps by utilising the endogeneity-robust Two-Step System-Generalized Method of Moments (SGMM) estimation approach that incorporate forward orthogonal deviations to generate reliable empirical findings (Saba et al. 2023). We employed the SGMM approach for several reasons. Firstly, it is known for its efficiency in dynamic panel data models, offering more precise parameter estimates (Wooldridge 2001). Secondly, it is robust in addressing endogeneity issues, a common challenge in econometrics (Wooldridge 2001). Thirdly, it allows for a greater number of momentary conditions, accommodating complex data structures (Wooldridge 2001). Lastly, it could be applied even when assumptions like homoskedasticity fail, rendering it versatile in various real-world scenarios (Wooldridge 2001). The fundamental/main research question which previous studies failed to address, and we seek to answer globally and regionally, is how they can achieve improved institutional quality by employing their sustainable policy instruments around ICTP. Therefore, the primary objective of this study is to explore the institutional quality effect of ICTP from both global and regional perspectives. By examining empirical evidence and conducting a comprehensive analysis, we could gain valuable insights into the relationship between ICT and institutions, and the potential mechanisms through which ICT influences institutional quality. We also examine the direction of causality between institutional quality and ICT penetration by applying the Dumitrescu-Hurlin (2012) panel causality technique to determine the causal relationship between the two variables.

On a global scale, understanding the overall relationship between ICT penetration and institutional quality will provide an opportunity to uncover: (1) the contribution that ICT penetration has made to the progress of institutional development, (2) the evaluation of additional control variables that may influence institutional quality, and (3) the establishment of a basis for policy recommendations and interventions at global level. However, it is also important to recognise that the impact of ICT penetration on institutional quality may vary across regions, due to the difference in socioeconomic context, level of technological advancement, and institutional framework. Therefore, the aim with this research is also to provide regional perspectives on the institutional quality effect of ICTP. The regional analysis will facilitate the identification of region-specific challenges and opportunities, enabling policymakers to design tailored strategies to enhance institutional quality through ICT development. The insight from this study will inform evidence-based policymaking, guide strategic interventions, and support the formulation of effective ICT policies, aimed at improving institutional quality.

The organisation of this paper is as follows: In Section 2 the review of previous studies is presented. In Section 3 the methodology and data are presented. Results from the empirical analysis are presented and discussed in Section 3. Finally, Section 4 is concluding with policy recommendations.

Literature review

ICT penetration refers …

> … [*T*]o the extent to which information and communication technologies are adopted and used in a particular region, sector, or context. It is a measure of the accessibility and utilisation of ICT-related infrastructure and services. (David & Grobler 2020:1395)

On the one hand, studies on the growth nexus of the ICT-institutions often reveal a favorable relationship, particularly in developed countries, considering these three variables. However, scholars and international organisations, such as Erdil, Yetkiner and Türkcan (2010), Simmie (2015), Entele (2021), Saba and Ngepah (2022c), the World Bank Group (2016), and many more, have highlighted through their studies the increasing significance of ICT in enhancing returns on investment, growth and productivity. On the other hand, some studies have unveiled a bidirectional causal relationship between ICT and growth, as exemplified by Veeramacheneni, Ekanayake and Vogel (2007), Saba and Ngepah (2022c), and Erdil et al. (2010), among others. However, this does not necessarily imply that mere access to ICT services and infrastructures will inevitably lead to greater growth. This is because the process of adapting to and embracing ICT at the global and regional levels requires the presence of institutions and good governance structures (Asongu & Nwachukwu 2016).

In line with Hellstrom (2008), ICT enhances institutions by promoting accountability, transparency, and information flow. ICT enables citizen engagement and information sharing both within and outside formal settings, hence, fostering societal connectivity and innovation. Having this in mind, Bailard (2009:337–339) theorises that limited ICT access among the elite in developing countries allowed corruption to thrive in institutions/societies. The gradual proliferation of ICT, among citizens, has diminished corruption opportunities and enhanced transparency, breaking the secrecy barriers. This theory aligns with Hellstrom's (2008) idea of ICT reducing elite information monopolies. Enhanced ICT infrastructure, encompassing accessibility, skill levels, and usage, influences institutional quality. Studies by Lio et al. (2011) and Shim and Eom (2008) reveal that ICT adoption reduces corruption. Robust ICT infrastructure also promotes freedom of expression, fostering government accountability and institutional quality (Shirazi 2008). Information and communications technology services/infrastructure advances e-government, improving service delivery, administration, and citizen engagement as mentioned earlier (Kudo 2008), while Institutional indicators/factors could at the same time affect ICT development negatively, thereby potentially deepening the global digital divide (Asongu & Nwachukwu 2016).

Institutions, according to a commonly accepted definition, 'are the humanly devised constraints that structure political, economic and social interactions' (North 1991:97).

Despite this definition, there is an ongoing debate on this, mainly involving two approaches. In one view institutions are seen as rules established by humans, creating exogenous constraints on behavior to reduce transaction costs and bring regularity to interaction (*the rule-based conception*) (North 1990). According to this perspective, enforcing rules is seen as separate from their formation, and the efficiency and predictability of rules are crucial to assessing institution quality (Alonso et al. 2020; Greif 2006). Conversely, some consider institutions as mainly endogenous and self-enforcing equilibria (*the equilibrium-based conception*) (Alonso et al. 2020; Greif 2006). Here, enforcement is often endogenised, with institutions as equilibria in repeated games. These institutions motivate individuals to act as expected, emphasising credibility and legitimacy as important factors in institutional quality (Alonso et al. 2020; Greif 2006).

While these approaches are not necessarily incompatible, according to a more eclectic view institutional quality is judged on four criteria: predictability, static and dynamic efficiency, and legitimacy (Alonso et al. 2020). Other criteria for good governance, like impartiality in the exercise of public authority or state autonomy (Rothstein & Teorell 2008), are seen as means to achieve these four functions. Empirically, analysing variables associated with these criteria is essential. Recent studies in economic development provide some insights by investigating the emergence of nation-states and modern legal orders in Western economies (see for example, Fukuyama 2011, 2014, among others), showing how institutions address external threats and internal violence. Another focuses on transitions from non-democratic to democratic regimes, highlighting the impact of wealth and income distribution on institutions (see for example, Acemoglu and Robinson 2001, 2006; Boix 2003, 2015; etc.). A third explores the mutual interaction and evolution of economic, political, and institutional forces (for example, Besley & Persson 2011; Gradstein 2003, etc.). These approaches provide a multifaceted view on institutional quality.

Based on the above discussions, institutional quality, according to empirical literature, could be linked to some potential determinants, namely, level of development (Besley & Persson 2011), inequality (Acemoglu & Robinson 2011; Chong & Gradstein 2007), tax revenue (Baskaran & Bigsten 2013; Bräutigam, Fjeldstad & Moore 2008), openness (Alonso & Garcimartín 2013; Rodrik et al. 2004), levels of education (Alonso & Garcimartín 2013; Glaeser et al. 2007 Besley & Persson 2011), among others. As mentioned earlier, Alonso and Garcimartín (2013) examined factors impacting institutional quality, finding positive influences from developmental level, the tax system, and income distribution. Alonso et al. (2020) expanded on Alonso and Garcimartín's (2013) study, by identifying further variables from the side of public policy that also shape institutional quality.

Despite the existing empirical literature on various factors influencing institutional quality, it is evident that prior studies have not delved deeply into the institutional quality – ICTP nexus at both global and regional levels. This omission

has implications for policy recommendations, particularly those directed toward achieving SDG 16, which emphasises the establishment and promotion of strong and inclusive institutions. Additionally, previous research is limited by constraints in terms of study duration and the number of countries under examination. To address these gaps, an endogeneity-robust SGMM estimation approach is employed in the present analysis as mentioned earlier. This approach incorporates forward orthogonal deviations to yield reliable empirical insights into the institutional quality– ICTP nexus. The study covers a broad spectrum of 183 countries, spanning the period from 2003 to 2021. Furthermore, the countries are disaggregated into five major regions to provide a comprehensive analysis. By embarking on this analysis more thoroughly, policymakers could develop strategies to harness the potential of ICT to enhance institutional quality. The policy relevance of this study lies in its potential to derive evidence-based recommendations for governments and international organisations seeking to improve institutional quality through ICT interventions. Policymakers could gain insights into the institutional quality effect of ICTP and how these effects vary across regions. This information may guide the development of targeted policies and investments to enhance institutional quality, promote good governance, and contribute to achieving broader developmental goals.

Methodology and data

Empirical strategy

The empirical strategy used in this study include PCA, descriptive analysis, scatter plot (graph) and the Two-step system-GMM to account for endogeneity issues. In this study, the GMM technique is utilised for estimation. The choice of this technique is motivated by specific factors unique to our data, as emphasised in Asongu and Nwachukwu (2016), Asongu and De Moor (2017), as well as Saba and Ngepah (2019). The first factor pertains to the necessary conditions for adopting the estimation strategy, while the last three factors relate to the advantages associated with the approach.

Firstly, at both the global and regional levels, the time dimension is smaller than the number of observations in each country (i.e., T < N). *Secondly*, the applied estimation technique adequately addresses potential endogeneity issues in all the series. *Thirdly*, the employed approach does not get rid of cross-country variations. *Fourthly*, considering the third advantage, Bond, Hoeffler and Tample (2001) recommend that the system-GMM technique, developed by Arellano and Bover (1995) and Blundell and Bond (1998), is a more appropriate choice compared to the previous one proposed by Arellano and Bond (1991), namely the difference estimator. Lastly, in this study, we employ the extension of Arellano and Bover (1995) by Roodman (2009a, 2009b), which replaces first differences with forward orthogonal deviations. This method has been shown to account for cross-country dependence, and mitigate the excessive use of instruments and over-identification issues (Baltagi 2008; Love & Zicchino 2006). To address heteroscedasticity, we adopt a two-step estimation technique in our specification, while the one-step estimation technique is consistent with homoscedasticity.

Principal components approach

In this study, the PCA technique was used to generate the ICTP index and institutional quality index (INSTQTY). For a concise explanation, PCA is necessary. Introduced by Karl Pearson in 1901 and further developed by Hotelling in 1933, PCA involves distilling information from high-dimensional indicator sets, creating new indices that capture important data on separate dimensions while maintaining their independence. It condenses numerous variables while retaining most of the initial data. To calculate the composite index for ICTP and INSTQTY, we utilised the first eigenvectors (loading matrix) from PCA as the necessary weights, leading to the following linear combination:

$$ICT = \varphi_1 LmobT + \varphi_2 LFLT + \varphi_3 LIAS \quad \text{[Eqn 1]}$$

$$INSTQTY = \ddot{\text{K}}_1 WGIcrrp + \ddot{\text{K}}_2 WGIpoli + \ddot{\text{K}}_3 WGIgef + \ddot{\text{K}}_4 WGIregq + \ddot{\text{K}}_5 WGIrul + \ddot{\text{K}}_6 WGIvoc \quad \text{[Eqn 2]}$$

where:φ_1, φ_2, and φ_3 are the eigenvectors (weights) from the PCA and mobT, FLT and IAS are the three synthetic of ICTP; and $\ddot{\text{K}}_1$, $\ddot{\text{K}}_2$, $\ddot{\text{K}}_3$, $\ddot{\text{K}}_4$, $\ddot{\text{K}}_5$, and $\ddot{\text{K}}_6$ are the eigenvectors (weights) from the PCA and *WGIcrrp*, *WGIpoli*, *WGIgef*, *WGIregq*, *WGIrul* and *WGIvoc* are the variables used to generate the quality of institutional index. The description of the variables in Equation 1 and Equation 2 can be found in Table 1 of this study.

Dumitrescu and Hurlin panel causality technique

To examine the direction of causality between our variables of interest (that is the institutional quality and ICTP), this study applied the pairwise Dumitrescu-Hurlin (2012) panel causality technique. The Pairwise Dumitrescu-Hurlin test was developed on the Granger causality test, and its merit over Granger causality is that its addresses heterogeneous characteristics of the countries. Thus, the following equations are used for the causality objective of this study:

$$W_{i,t} = \tau_{1i,t} + \sum_{j=1}^{p} \beta_{1i}^{(j)} W_{i,t-j} + \sum_{j=1}^{p} \lambda_{1i}^{(j)} X_{i,t-j} + \mu_{1i,t} \quad \text{[Eqn 3]}$$

where W, X, β & λ, i, t, p, τ and μ are the dependent variable, vector of explanatory variable(s), slope coefficients, units (countries), time period, number of lag length, intercepts and the error terms, respectively. Details of the variables can be found in Table 1.

Brief theoretical underpinning and empirical model specification

Our model specification is based on the economic development theory, which suggests that institutional quality is influenced by multiple factors such as socioeconomic, macroeconomic, and demographic factors. Additionally, we incorporate the Technology-Organization-Environment (TOE) theoretical

TABLE 1: Variable description and sources.

Variables	Description	Sources
ICTP	ICT penetration (ICTP) is captured by a composite index of ICT development indicators (which comprises of three indicators) by applying principal components method/ analysis (PCA) (Saba et al. 2023). These indicators include: (i) mobile-cellular telephone subscriptions per 100 inhabitants (penetration of connected mobile lines) (LmobT) (Saba et al. 2023); (ii) fixed-telephone subscriptions per 100 inhabitants (LFLT) (Saba et al. 2023); and (iii) percentage of individuals using the Internet (LIAS) (Saba et al. 2023).	ITU database
LGDPC	*Log of* GDP per capita (constant 2010 US$) (Saba et al. 2023)	WDI database
LGFCF	*Log of g*ross fixed capital formation (% of GDP) proxy for investment (Saba et al. 2023)	WDI database
LFDEV	*Log of d*omestic credit to private sector (% of GDP) proxy for financial development (Saba et al. 2023)	WDI database
FDI	Foreign direct investment, net inflows (% of GDP) (Saba et al. 2023)	WDI database
LTRD	*Log of* Trade (% of GDP) proxy for trade openness (Saba et al. 2023)	WDI database
LHUM	*Log of* School enrollment, secondary (% gross) proxy for human capital endowments (Saba et al. 2023)	WDI database
LPOP	*Log of* Population, total (Saba et al. 2023)	WDI database
Institutional quality index (INSTQTY) variable obtained from governance indicators (Saba et al. 2023)		
WGIcrrp	Control of Corruption (Saba et al. 2023)	WGI database
WGIpoli	Political stability and absence of violence/terrorism (Saba et al. 2023)	WGI database
WGIgef	Government effectiveness (Saba et al. 2023)	WGI database
WGIregq	Regulatory quality (Saba et al. 2023)	WGI database
WGIrul	Rule of law (Saba et al. 2023)	WGI database
WGIvoc	Voice and accountability (Saba et al. 2023)	WGI database

Source: Saba, C.S. & Ngepah, N., 2023, 'Empirics of convergence in industrialisation and their determinants: Global evidence', *Discover Sustainability* 4(1), 25. https://doi.org/10.1007/s43621-023-00136-8

WDI, the World Bank's world development indicators; ITU, international telecommunication union database; WGI, the World Bank's world governance indicators.

framework, which emphasises that a firm's decisions regarding technological innovations and adoption are influenced by three contextual factors: technological, organisational, and environmental contexts (Adam 2020; Tomatzky & Fleischer 1990). For example, Gradstein (2003, 2008) presents a model that establishes a mutually beneficial relationship between economic growth/development and institutional quality. According to the Scholar, investment is fractionally allocated to rent-seeking, determined by property rights enforcement. Financing the public good of enforcement requires national income/growth, innovative financing mechanisms, public borrowing/debt financing etc. Institutional quality improves economic growth and safeguards property rights by expanding the revenue base of the government (Alonso & Garcimartín 2013; Gradstein 2003, 2008). The model specification of this study follows the previous studies of Gradstein (2003, 2008), Alonso and Garcimartín (2013), Alonso et al. (2020) with modifications. Therefore, we specify our model as follows:

$$INSTQTY_{i,t} = f(X_{i,t}) \quad \text{[Eqn 4]}$$

$$INSTQTY_{i,t} = \beta_0 + \text{ב}_0 X_{i,t} \quad \text{[Eqn 5]}$$

$$INSTQTY_{i,t} = \beta_0 + \text{ב}_0 X_{i,t} + \varepsilon_{it} \quad \text{[Eqn 6]}$$

Where *INSTQTY* and *X* represents *INSTQTY* index and regressors,[1] respectively. We specify the system-GMM model below which took its bearing from Equation 6.

$$INSTQTY_{i,t} = \beta_0 + \beta_1 INSTQTY_{i,t-1} + \text{ב}_1 LICTP_{it} + \text{ב}_4 LGDPC_{it} + \text{ב}_5 LGFCF_{it} + \text{ב}_6 LFDEV_{it} + \text{ב}_7 FDI_{it} + + \text{ב}_8 LHUM_{it} + \text{ב}_9 LTRD_{it} + \text{ב}_{12} LPOP_{it} + + \text{ט}_i + \ell_t + \varepsilon_{it} \quad \text{[Eqn 7]}$$

Where β & ב, ε_{it}, ט_i and ℓ_t represents the coefficient of the lagged regressand variable, error term, country- specific and time-specific effects, respectively. ט_i and ℓ_t measure country-specific and time-specific effects respectively. ε_{it} is the error term (Saba et al. 2023). The details of both the regression and the explanatory variables can be found in Table 1. The above Equation 7 follows the system-GMM specification. The explanatory variables utilised in our model are the factors that determine institutional quality and therefore follow brief justifications for their inclusion in our model:

- **Real GDP per capita (proxy for levels of income/ growth):** We incorporated GDP per capita as one of our explanatory variables because empirical literature has shown that higher GDP per capita is associated with better institutional quality. This is because, as countries experience economic growth and development, they tend to invest in building strong institutions, including transparent governance systems, effective legal frameworks, and efficient public administration. Improved institutional quality, in turn, could facilitate further economic growth (Acemoglu, Johnson & Robinson 2001; Rodrik et al. 2004).
- **Financial development:** It could influence institutional quality by promoting transparency, accountability, and efficient resource allocation. A well-developed financial system provides access to capital, facilitates investment, and fosters economic growth, leading to better institutions. Studies such as that of Beck, Demirgüç-Kunt and Levine (2003) have highlighted the link between financial development and institutional quality.
- **ICT penetration:** Studies such as Imhonopi and Urim (2011) and Dias Canedo et al. (2020) have emphasised the significance of ICTP in societies, as it may enhance institutional quality through various means. These include improving transparency, efficiency, and access to information, as well as facilitating communication, data sharing, and public participation. Such advancements ultimately contribute to better governance and institutional performance.
- **Trade openness:** Studies such as Wei (2000), Le, Kim and Lee (2016), Rodrik (2000), Rodriguez and Rodrik (2000), among others, have emphasised the significance of trade openness in countries, as it may contribute to better governance and institutional development through various means, namely, through promoting economic liberalisation, competition, and accountability. Trade openness often requires countries to undertake economic

1.Due to the governing rules, it is important for the reader to take note that we did not log variables with negative values (Saba et al., 2023).

reforms and liberalisation measures, such as reducing trade barriers and implementing market-oriented policies. These reforms could lead to improvements in institutional quality by fostering competition, efficiency, and accountability as partly mentioned. Trade openness can also expose countries to new ideas, technologies, and knowledge from abroad. This exchange of information could enhance institutional quality by introducing innovative practices, promoting learning, and challenging outdated norms and regulations (Rodrik 2000; Rodriguez & Rodrik 2000).

- **Human capital:** Human capital, particularly education and skills, contributes to institutional quality by fostering a knowledgeable and capable workforce. Well-educated individuals are more likely to understand and support the importance of institutions, leading to better governance, accountability, and the ability to adapt to changing circumstances (Acemoglu et al. 2001; Hall & Jones 1999); therefore, playing a critical role in the formulation and implementation of effective policies and institutional reforms. Well-educated individuals with expertise in economics, law, and public administration could also contribute to the design of sound policies, regulatory frameworks, and governance structures (Arvin 1999; Acemoglu et al. 2001).
- **Foreign direct investment (FDI):** FDI often brings advanced technologies, managerial practices, and knowledge to host countries. These transfers may contribute to improving institutional quality by enhancing productivity, efficiency, and innovation (Blomstrom & Kokko 2003; Borensztein, De Gregorio & Lee 1998). The presence of multinational corporations (MNCs), through FDI, may lead to positive externalities, promoting the adoption of better institutional practices (Aitken & Harrison 1999). It may act as a catalyst for institutional reforms and policy stability. This is because host countries often implement institutional changes to attract and retain foreign investors. These reforms could include streamlining bureaucratic processes, strengthening legal systems, protecting property rights, and reducing corruption (Borensztein et al. 1998; Globerman & Shapiro 2002).
- **Population size:** A larger population usually require a broader range of public goods and services, such as infrastructure, healthcare, education, and security. Meeting these demands requires effective governance and institutions capable of efficiently allocating resources and providing essential services (Acemoglu, Johnson & Robinson 2005). Hence, the need to incorporate the variable into our model.
- **Gross fixed capital formation proxy for investment:** Increased levels of investment in the economy could lead to stronger institutions because the government would be motivated to enhance institutional strength in order to gain the confidence of both domestic and foreign investors. Moreover, institutional quality plays a vital role in inspiring investor confidence, as it assures them that their investments will be secure and yield returns (Knack & Keefer 1995).

We included the aforementioned explanatory variables in our model based on empirical literature, which has indicated their potential to influence institutional quality in various ways.

Data and variables description

The study utilised yearly panel data from 183 nations covering the period from 2003 to 2021. These nations were divided into five primary regions according to the World Bank's regional divisions: sub-Saharan Africa with 45 countries, the Middle East and North Africa with 20 countries, Europe and Central Asia with 47 countries, East and South Asia, the Pacific with 35 countries, as well as the Americas with 36 countries. The main sources of data were the World Bank's World Development Indicators and World Governance Indicators, as well as data from the International Telecommunication Union. This research follows the precedent of using ITU indicators as established by prior research (refer to David & Grobler 2020; Saba & David 2020; Saba & Ngepah 2022c, among others). The choice of the specific time period and the countries included was based on the availability of data. Indices for ICTP and institutional quality were calculated from indicators listed in Table 1, using PCA as previously mentioned. Table 1 and Table 2 provide a list of the variables and the countries examined in this study, respectively.

There were missing data, but this was handled by means of interpolation and extrapolation of data.[2]

Empirical results and discussion

Principal component analysis

Table 3 presents the principal component approach and correlation matrix results for institutional quality (INSTQTY) and ICTP variables for the full sample, while the PCA results for the regional ones were not provided to save space, but can be made available upon request. We firstly started by testing whether or not there are some degree of association between the indicators used to generate an index for each of the variables, that is, INSTQTY and ICTP (Saba et al. 2023). The results in Panel A and B show that the indicators are strongly correlated, hence, we proceeded to the estimation of the PCA, given that the condition of the indicators being correlated, was filled (Saba & Ngepah 2022a, 2022b, 2022c). At the global and regional levels, to create a composite index for INSTQTY and ICTP, we selected the first principal component that explains the highest percentage of the total variation (Saba et al. 2023). For the globe level, we selected the first component of the INSTQTY variable because its eigenvalue accounts for 5.51%, which is the highest percentage of the total variation (Saba et al. 2023). Likewise, we chose the first component for the ICTP variable, because its eigenvalue accounts for 2.39%, the highest percentage of the total variation (Saba et al. 2023). We applied the same rule of thumb to the others regions (Saba et al. 2023).

TABLE 2: List of countries classified into five regions.

Country ID (cid)	sub-Saharan Africa (SSA)	Middle East and North Africa (MENA)	Europe & Central Asia (ECA)	East & South Asia and the Pacific (ESAP)	America
1	Angola	Algeria	Albania	Afghanistan	Antigua and Barbuda
2	Benin	Bahrain	Armenia	Australia	Argentina
3	Botswana	Djibouti	Austria	Bangladesh	Aruba
4	Burkina Faso	Egypt, Arab Rep.	Azerbaijan	Bhutan	Bahamas
5	Burundi	Iran, Islamic Rep.	Belarus	Brunei Darussalam	Barbados
6	Cabo Verde	Iraq	Belgium	Cambodia	Belize
7	Cameroon	Israel	Bosnia and Herzegovina	China	Bolivia
8	Central African Rep.	Jordan	Cyprus	Fiji	Brazil
9	Chad	Kuwait	Czech Republic	Hong Kong SAR, China	Chile
10	Congo (Rep. of the)	Lebanon	Denmark	India	Colombia
11	Cote d'Ivoire	Libya	Estonia	Indonesia	Costa Rica
12	Dem. Rep. of the Congo	Malta	Faroe Islands	Japan	Cuba
13	Equatorial Guinea	Morocco	Finland	Kiribati	Dominica
14	Eritrea	Oman	France	Korea, Rep.	Dominican Republic
15	Eswatini	Qatar	Georgia	Lao PDR	Ecuador
16	Ethiopia	Saudi Arabia	Germany	Macao SAR, China	El Salvador
17	Gabon	Syrian Arab Republic	Greece	Malaysia	Grenada
18	Gambia	Tunisia	Greenland	Maldives	Guatemala
19	Ghana	United Arab Emirates	Hungary	Micronesia, Fed. Sts.	Guyana
20	Guinea	Yemen, Rep.	Iceland	Mongolia	Haiti
21	Guinea-Bissau	-	Ireland	Myanmar	Honduras
22	Kenya	-	Italy	Nepal	Jamaica
23	Lesotho	-	Kazakhstan	New Caledonia	Mexico
24	Liberia	-	Kyrgyz Republic	New Zealand	Nicaragua
25	Madagascar	-	Latvia	Pakistan	Panama
26	Malawi	-	Lithuania	Philippines	Paraguay
27	Mali	-	Luxembourg	Samoa	Peru
28	Mauritania	-	Moldova	Singapore	Puerto Rico
29	Mauritius	-	Montenegro	Sri Lanka	Saint Kitts and Nevis
30	Mozambique	-	Netherlands	Thailand	Saint Vincent and the Grenadines
31	Namibia	-	North Macedonia	Timor-Leste	Suriname
32	Niger	-	Norway	Tonga	Uruguay
33	Nigeria	-	Poland	Tuvalu	Venezuela, RB
34	Rwanda	-	Portugal	Vanuatu	Bermuda
35	Sao Tome and Principe	-	Romania	Vietnam	Canada
36	Senegal	-	Russian Federation	-	United States
37	Seychelles	-	Serbia	-	-
38	Sierra Leone	-	Slovak Republic	-	-
39	South Africa	-	Slovenia	-	-
40	Sudan	-	Spain	-	-
41	Tanzania	-	Sweden	-	-
42	Togo	-	Tajikistan	-	-
43	Uganda	-	Turkey	-	-
44	Zambia	-	Turkmenistan	-	-
45	Zimbabwe	-	Ukraine	-	-
46	-	-	United Kingdom	-	-
47	-	-	Uzbekistan	-	-

Source: WDI database

Summary statistics and scatter plot analysis

Table 4 displays the results of the descriptive statistics. These statistics include the mean (or median) values for the variables being analysed. The mean signifies the average value for a variable, and the median signifies the central value when the variable's values are ranked from lowest to highest. For the two primary series we considered, ICTP and institutional quality (INSTQTY), the mean (or median) figures are roughly –0.163 (0.317) and –0.004 (0.417), respectively. An examination of the mean (or median) values indicates that the population variable (LPOP) has the largest value, with a mean of 15.740 (or a median of 15.849), implying a significantly large global population. Conversely, the institutional quality variable records the smallest value, with a mean of –0.004 (or a median of 0.417). This rationale applies to the remaining variables as well. The variables' values range from a maximum of 449.083 to a minimum of –3.283. A series demonstrating a negative skewness indicates a distribution that leans towards lower values for the variables, while the presence of negative skewness also confirms this negatively skewed distribution. Additionally, the Jarque-

TABLE 3: Principal component and correlation matrix results for institutional quality, and Information and communications technology penetration variables.

Variable	Principal component results				Principal components eigenvectors results							Correlation matrix results								
	Eigenvalue	Difference	Proportion	Cumulative	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6	Un explained	*WGIcrrp*	*WGIpoli*	*WGIgef*	*WGIregq*	*WGIrul*	*WGIvoc*	LFLT	LmobT	LIAS
Panel (A): Institutional quality index variable																				
Component 1	5.512	5.145	0.919	0.919	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 2	0.367	0.279	0.061	0.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 3	0.088	0.072	0.015	0.995	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 4	0.016	0.003	0.003	0.997	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 5	0.013	0.01	0.002	0.999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 6	0.003	-	0.001	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WGIcrrp	-	-	-	-	0.422	-0.148	0.152	-0.168	-0.673	-0.544	0.017	-	-	-	-	-	-	-	-	-
WGIpoli	-	-	-	-	0.397	0.47	-0.737	-0.277	0.02	0.035	0.13	-	-	-	-	-	-	-	-	-
WGIgef	-	-	-	-	0.417	-0.321	-0.039	0.227	-0.337	0.746	0.042	-	-	-	-	-	-	-	-	-
WGIregq	-	-	-	-	0.418	-0.228	0.342	-0.651	0.472	0.099	0.039	-	-	-	-	-	-	-	-	-
WGIrul	-	-	-	-	0.412	-0.377	-0.229	0.547	0.45	-0.367	0.065	-	-	-	-	-	-	-	-	-
WGIvoc	-	-	-	-	0.382	0.679	0.513	0.347	0.089	0.039	0.194	-	-	-	-	-	-	-	-	-
WGIcrrp	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
WGIpoli	-	-	-	-	-	-	-	-	-	-	-	0.890*** (0.000)	1	-	-	-	-	-	-	-
WGIgef	-	-	-	-	-	-	-	-	-	-	-	0.988*** (0.000)	0.859*** (0.000)	1	-	-	-	-	-	-
WGIregq	-	-	-	-	-	-	-	-	-	-	-	0.986*** (0.000)	0.856*** (0.000)	0.981*** (0.000)	1	-	-	-	-	-
WGIrul	-	-	-	-	-	-	-	-	-	-	-	0.971*** (0.000)	0.849*** (0.000)	0.991*** (0.000)	0.969*** (0.000)	1	-	-	-	-
WGIvoc	-	-	-	-	-	-	-	-	-	-	-	0.858*** (0.000)	0.919*** (0.000)	0.798*** (0.000)	0.835*** (0.000)	0.767*** (0.000)	1	-	-	-
Panel (B): ICT penetration index variable																				
Component 1	2.39	1.824	0.797	0.797	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 2	0.567	0.524	0.189	0.986	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Component 3	0.043	-	0.014	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LFLT	-	-	-	-	0.506	0.825	0.253	-	-	-	0.388	-	-	-	-	-	-	-	-	-
LmobT	-	-	-	-	0.585	-0.544	0.602	-	-	-	0.183	-	-	-	-	-	-	-	-	-
LIAS	-	-	-	-	0.634	-0.157	-0.757	-	-	-	0.039	-	-	-	-	-	-	-	-	-
LFLT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
LmobT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.460*** (0.000)	1	-
LIAS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.686*** (0.000)	0.915*** (0.000)	1

ICT, information and communications technology; Cmpnt, component.

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$; p-value in parentheses.

TABLE 4: Descriptive statistics results.

Statistics	ICTP	INSTQTY	LGFCF	LGDPC	LHUM	LTRD	LPOP	LFDEV	FDI
Mean	-0.163	-0.004	3.096	8.491	4.251	4.332	15.740	3.547	6.035
Median	0.317	0.417	3.083	8.840	4.409	4.253	15.849	3.736	3.056
Maximum	1.669	3.330	3.339	9.680	4.689	4.638	16.135	4.315	449.083
Minimum	-4.786	-3.283	2.845	6.956	3.385	4.097	15.153	2.243	-58.323
Std. Dev.	1.607	2.331	0.119	0.920	0.391	0.170	0.257	0.596	18.321
Skewness	-0.974	0.006	0.123	-0.428	-0.829	0.345	-1.221	-0.761	14.088
Kurtosis	3.267	1.676	2.731	1.703	2.277	1.526	3.176	2.413	265.914
Jarque-Bera	442.282	200.350	15.136	276.076	373.719	302.703	684.669	304.164	7990997.
Probability	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Observations	2743	2743	2743	2743	2743	2743	2743	2743	2743

ICTP, ICT penetration; INSTQTY, institutional quality; LGFCF, *log of* gross fixed capital formation; LGDPC, *log of* GDP per capita; LHUM, *log of* school enrolment; LPOP, *log of* population; LFDEV, *log of* domestic credit to private sector; FDI, foreign direct investment.

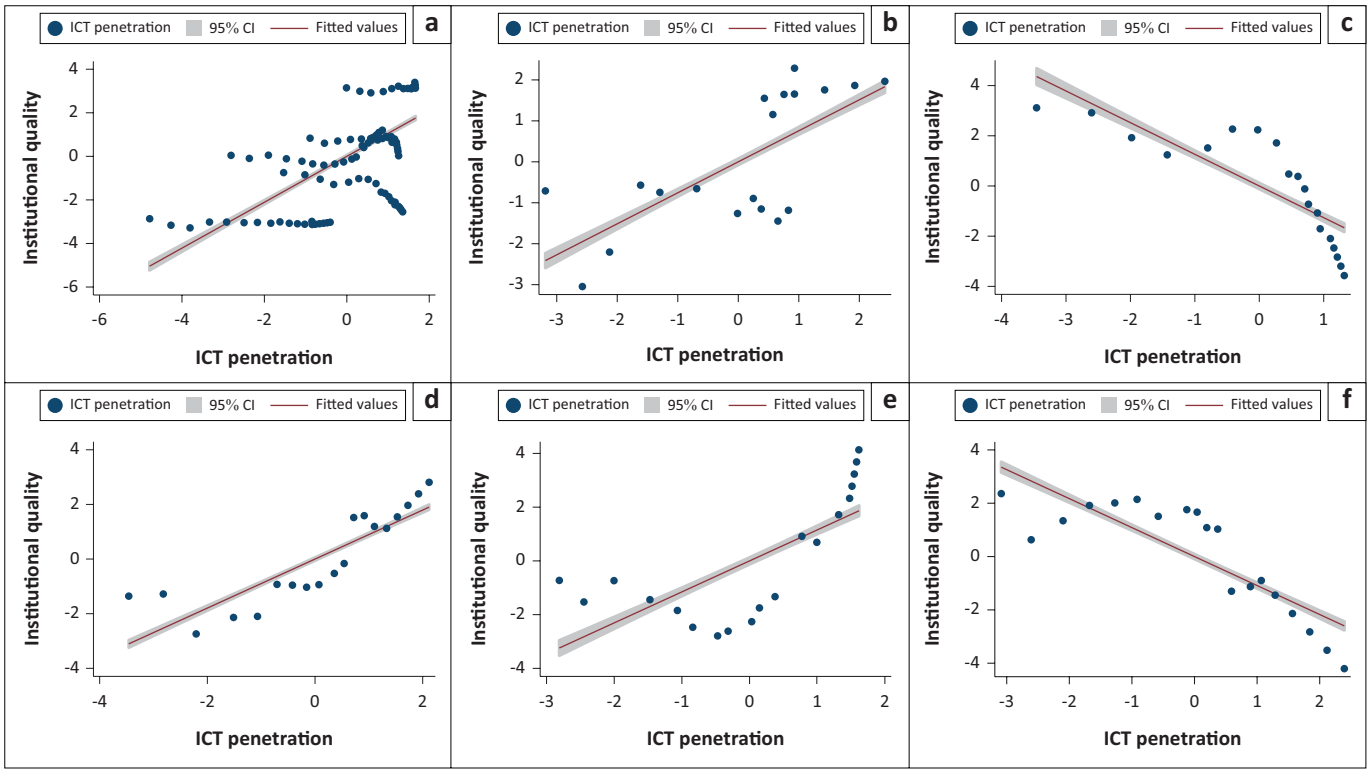

FIGURE 1: (a) Scatter plot between institutional quality and Information and communications technology penetration for the Full Sample; (b) Scatter plot between institutional quality and Information and communications technology penetration for the sub-Saharan Africa; (c) Scatter plot between institutional quality and ICT penetration into the Middle East and North Africa; (d) Scatter plot between institutional quality and ICT penetration into Europe & Central Asia; (e) Scatter plot between institutional quality and ICT penetration into East & South Asia and the Pacific; (f) Scatter plot between institutional quality and ICT penetration into America.

Bera statistics indicate deviations from a normal distribution in the variables at a 10% level of significance or higher (Saba & Ngepah 2023).

Turning our attention to the key variables, Figure 1 offers scatter plots that illustrate the correlation between institutional quality and ICTP on global and regional scales. The scatter plots show a positive correlation between the two variables at the global level, as well as within regions such as SSA, ECA, and ESAP, whereas a negative correlation is observed within the MENA and American regions. It is important to acknowledge that these scatter plots are not definitive in establishing causality due to potential endogeneity; they are intended only to suggest a possible link between institutional quality and ICTP.

Panel causality and Two-step system-generalized method of moments analysis

In this section the causal relationship between our main variables of interest, that is, the institutional quality and ICTP for the full sample and regions is analysed. Table 5 presents the panel causality test results. In Table 5, two-way causality exists between institutional quality and ICTP. We rejected the null hypothesis that there was no causation for each Chi square-value statistic since their *p*-values were less than 10% significance level. The two-way causality between our variables of interest suggested the need to account for endogeneity problems in our regression model, hence we applied the endogeneity-robust Two-Step SGMM estimation approach that incorporate forward orthogonal deviations to generate reliable empirical results.

TABLE 5: Dumitrescu and Hurlin (2012) panel causality test results.

Model	Direction of relationship observed	Conclusion	Null hypothesis	W-statistic	Zbar-statistic	*p-value*
Full Sample						
1	INSTQTY ↔ ICTP	Bidirectional causality	INSTQTY ↛ ICTP	4.017***	28.223	0.000
			ICTP↛ INSTQTY	3.265***	21.191	0.000
SSA						
2	INSTQTY ↔ ICTP	Bidirectional causality	INSTQTY↛ICTP	6.657***	26.834	0.000
			ICTP↛INSTQTY	0.019***	-4.653	0.000
MENA						
3	INSTQTY ↔ ICTP	Bidirectional causality	INSTQTY↛ ICTP	0.350***	-2.057	0.040
			ICTP↛ INSTQTY	0.087***	-2.886	0.004
ECA						
4	INSTQTY ↔ ICTP	Bidirectional causality	INSTQTY↛ ICTP	7.821***	32.353	0.000
			ICTP↛ INSTQTY	1.227*	1.075	0.082
ESAP						
5	INSTQTY ↔ ICTP	Bidirectional causality	INSTQTY↛ ICTP	6.368***	21.471	0.000
			ICTP↛ INSTQTY	0.662*	1.351	0.077
America						
6	INSTQTY ↔ ICTP	Bidirectional causality	INSTQTY↛ ICTP	1.375**	1.522	0.028
			ICTP↛ INSTQTY	12.973***	48.636	0.000

Note: ICTP, information and communications technology penetration; INSTQTY, institutional quality; MENA, Middle East and North Africa; SSA, Sub-Saharan Africa; ECA, Europe & Central Asia; ESAP, East & South Asia and the Pacific

↔ and → denote bidirectional and unidirectional causality respectively. ↛ denote does not homogeneously cause (i.e $\mathbf{H}_0$)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6 presents the findings on the institutional quality effect of ICTP at the global and regional levels. We initiate this sub-section by analysing the diagnostic test results to assess the reliability of the estimated outcomes. Table 6 display the results of diagnostic tests, indicating that the AR(2), Sargan OIR, instruments at levels (Hansen excluding group & Dif [null, H = exogenous]), GMM instruments for IV (Hansen excluding group & Dif [null, H = exogenous]), and Fisher statistics tests support the correctness of our model specifications. These results provide a solid basis for policy discussions and inferences.

By examining our main variables of interest, Table 6 reveals several noteworthy findings at the global and regional levels. *Firstly*, the positive and significance of the lagged dependent variable (i.e., INSTQTY) suggests that countries initially with bad institutions are gradually converging towards the countries with good institutions both at the global and regional levels. *Secondly*, in Column 1 of Table 6, *holding other variables constant*, ICTP exerts a positive and significant impact on INSTQTY, indicating its contribution to global institution quality. This implies that a 1% increase in ICTP will lead to a 0.07% increase in INSTQTY. This concurs with the findings of Shim and Eom (2008), Shirazi (2008) and Lio et al. (2011). This finding reinforces the importance of ICTP in achieving SDG 16. This implies that advancements in technology could enhance governance, transparency, and efficiency in various domains. By enabling better communication, information sharing, and access to digital services, ICT may contribute to improved institutional frameworks, which will lead to more effective public administration, better regulatory environments, and increased accountability.

Thirdly, in Column 2 of Table 6, *holding other variables constant*, ICTP exerts a negative and significant impact on INSTQTY, indicating its inadequate contribution to SSA's INSTQTY. This implies that a 1% increase in ICTP will lead to a –1.97% decrease in INSTQTY. This finding may be contrary to expectations, possibly due to the presence of indirect factors associated with ICTP that may have the potential to influence institutional quality, but were not directly examined in this study. For example, SSA faces several challenges in the development and adoption of ICT, and these include, amongst others, infrastructure limitations, socioeconomic disparities, and policy constraints (Asongu, Orim & Nting 2019; Kouladoum, Wirajing & Nchofoung 2022). *Fourthly*, in Column 3 and 5 of Table 6, *holding other variables constant*, ICTP exerts a negative and significant impact on INSTQTY, indicating its inadequate contribution to MENA and ESAP's INSTQTY. This implies that a 1% increase in ICTP will result in a –0.42% decrease in MENA's INSTQTY and a –1.14% decrease in ESAP's INSTQTY. Furthermore, contrary to expectations, the findings for MENA and ESAP regions could also be attributed to indirect factors associated with ICTP that have the potential to influence institutional quality in these regions. However, these factors were not directly examined in this study. For example, (1) some countries in the MENA region impose strict internet censorship and surveillance measures, which could limit online freedom of expression, restrict access to certain websites, and hinder the development of a free and open digital environment (Kalathil & Boas 2001). All of these challenges, and even more, could influence the development of the institutions in that region.

Fifthly, in Column 4 and 6 of Table 6, *holding other variables constant*, ICTP exerts a positive and significant impact on INSTQTY, indicating its contribution to ECA and America's INSTQTY. This implies that a 1% increase in ICTP will result in a 0.45% improvement in ECA's INSTQTY and a 1.47% improvement in America's INSTQTY. For example, studies such as Lau et al. (2015) and Kelly et al. (2017) have demonstrated that the ECA region has made substantial progress in ICT development, including broadband penetration, mobile connectivity, digital skills and literacy, and digital innovation and startups. From the results of this study, these advancements have shown to positively influence institutional development in the region.

Conclusion and policy recommendations

As countries at global and regional levels work towards achieving the United Nations SDG 16, which emphasises the establishment and promotion of strong and inclusive institutions, there is a growing urgency to harness the power of ICTP to accomplish this objective. Hence, it is imperative to investigate the potential contributions of ICTP in advancing institutional quality on a global and regional scale. The study covers the period from 2003 to 2021, and we utilised the endogeneity-robust Two-Step SGMM estimation approach, incorporating the consideration of forward orthogonal

TABLE 6: Two-step system-generalized method of moments results.

Variables	Full sample			SSA			MENA			ECA			ESAP			America		
	SGMM	SE 1	*p*-value	SGMM	SE 2	*p*-value	SGMM	SE 3	*p*-value	SGMM	SE 4	*p*-value	SGMM	SE 5	*p*-value	SGMM	SE 6	*p*-value
INSTQTY (-1)	1.023***	0.000	-	0.069***	0.000	-	0.142***	0.018	-	0.158***	0.000	-	0.493***	0.049	-	0.253**	0.106	-
ICTP	**0.068*****	**0.001**	-	**-1.969*****	**0.000**	-	**-0.422*****	**0.053**	-	**0.446*****	**0.000**	-	**-1.136*****	**0.302**	-	**1.468****	**0.590**	-
LLGDPC	-0.287***	0.002	-	0.254***	0.003	-	-0.346***	0.152	-	0.980***	0.002	-	0.580	0.193	-	0.079	0.072	-
FDI	0.002***	0.000	-	-0.006***	0.000	-	-0.040***	0.009	-	0.012***	0.000	-	-0.421***	0.133	-	-0.274*	0.145	-
LLGFCF	0.230***	0.005	-	0.047***	0.001	-	1.181***	0.145	-	0.687***	0.001	-	-0.177***	0.287	-	0.056**	0.013	-
LLFDV1	0.089***	0.003	-	-0.635***	0.003	-	-0.873***	0.091	-	-0.254***	0.000	-	-1.554	1.294	-	-0.090***	0.065	-
LLHUM	-0.068***	0.007	-	-0.507***	0.008	-	-0.365***	0.158	-	0.209***	0.002	-	1.659	1.665	-	-0.440	0.036	-
LLPOP	-0.319***	0.002	-	0.043***	0.010	-	0.398***	0.831	-	-0.316***	0.001	-	0.039***	0.235	-	-0.502*	0.010	-
LLTRD	0.737***	0.003	-	-0.730***	0.002	-	-0.304***	0.087	-	-0.097***	0.000	-	0.880***	0.688	-	0.844*	0.097	-
Constant	0.511***	0.045	-	-0.920***	0.132	-	0.838	0.504	-	0.000	0.000	-	-0.256***	0.715	-	0.075	0.017	-
Diagnostic test results																		
AR(1)	-	-8.93	0.000	-	-6.67	0.000	-	**1.05**	**0.294**	-	**-1.47**	**0.141**	-	-2.83	0.005	-	-2.84	0.005
AR(2)	-	**-0.94**	**0.349**	-	**1.92**	**0.254**	-	**-1.33**	**0.183**	-	**-0.81**	**0.420**	-	**-0.08**	**0.935**	-	**-2.34**	**0.219**
Sargan OIR	-	**840.54**	**1.022**	-	**669.46**	**1.260**	-	**8.61**	**0.569**	-	**5.58**	**0.589**	-	**67.76**	**1.130**	-	**62.16**	**1.000**
Hansen OIR	-	**173.44**	**0.223**	-	**45.00**	**0.316**	-	**19.81**	**0.231**	-	**14.31**	**0.146**	-	**29.79**	**0.530**	-	**21.92**	**0.209**
DHT for instruments	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(a) Instruments at levels	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hansen excluding group	-	**173.43**	**0.113**	-	**45.01**	**0.606**	-	**19.81**	**0.511**	-	**14.31**	**0.226**	-	**29.79**	**0.401**	-	**21.92**	**0.504**
Dif(null, H=exogenous)	-	**0.00**	**0.999**	-	**-0.01**	**1.000**	-	**0.00**	**1.000**	-	**0.00**	**1.000**	-	**0.00**	**1.000**	-	**-0.00**	**1.000**
(b) GMM instruments for IV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hansen excluding group	-	**173.40**	**0.101**	-	**45.00**	**0.504**	-	**19.81**	**0.406**	-	**14.31**	**0.114**	-	**29.93**	**0.311**	-	**21.82**	**0.403**
Dif(null, H=exogenous)	-	**0.04**	**0.998**	-	**0.00**	**1.000**	-	**0.00**	**1.000**	-	**0.00**	**1.000**	-	**-0.15**	**1.000**	-	**0.10**	**0.949**
Fisher	**5.03e+06*****	-	-	**5.01e+09*****	-	-	**29926.24*****	-	-	**8.06e+10*****	-	-	**827.68*****	-	-	**94.82*****	-	-
Instruments	36	-	-	37	-	-	20	-	-	33	-	-	19	-	-	19	-	-
Observations	2,572	-	-	668	-	-	289	-	-	669	-	-	470	-	-	476	-	-

Note: The significance of bold values holds two key implications. Firstly, it relates to the significance of estimated coefficients and the Fisher statistics. Secondly, it signifies the non-rejection of null hypotheses, specifically (a) the absence of autocorrelation in the AR(2) tests, and (b) the validity of the instruments in the Sargan OIR test.

DHT, Difference in Hansen Test for Exogeneity of Instruments Subsets; Diff, Difference; OIR, Over-identifying Restrictions Test; SSA, sub-Saharan Africa; MENA, Middle East and North Africa; ECA, Europe & Central Asia; ESAP, East & South Asia and the Pacific; SGMM, system-generalized method of moments; INSTQTY, institutional quality; ICTP, ICT penetration; LGDPC, log of GDP per capita; LGFCF, log of gross fixed capital formation; LFDEV, log of domestic credit to private sector; FDI, foreign direct investment; LTRD, log of trade; LHUM, log of school enrolment; LPOP, log of population; SE, Standard error.

***,**,*: significance levels at 1%, 5% and 10% respectively.

deviations, which distinguishes it from the SGMM approach that neglects such considerations (Roodman 2009a, 2009b). This research sets itself apart from previous literature by creating a composite index for ICT, which includes three variables listed in Table 1, as well as an index for institutional quality, derived from six governance indicators listed in Table 1, using PCA. Additionally, it incorporates additional explanatory variables which can be found in Table 1.

This study contributes to the literature by presenting the following results. Focusing on our variables of interest, the estimation results using the endogeneity-robust Two-Step SGMM approach, indicate the following: (1) Across the full sample, as well as in the ECA and America regions, ICTP has a positive and significant impact on INSTQTY, highlighting its contribution to global and regional institutional quality. (2) However, in SSA, MENA, and ESAP regions, ICTP exhibits a negative and significant impact on institutional quality, indicating a retrogressive contribution to institutional quality in these specific regions.

To achieve SDG 16 here are some policy directions based on the findings of this study: (1) policymakers and governments at the global level should utilise ICT to gain deeper insight into the problems facing institutional development in order to further promote its contribution to institutional quality. Although ICTP contributes to the improvement of institutional quality on global scale, further policies that deepen global cooperation and investment in ICT development among governments should be innovated, implemented, and reviewed on a continual basis, considering the current global levels of rural – urban and gender digital divide (ITU 2021). (2) To enhance institutional quality in the SSA, MENA, and ESAP regions, it is essential for regional governments to establish and execute policies that encourage collaboration and investment in the ICT industry. Additionally, the governments should identify and address the challenges they may face in facilitating mutual access to the global ICT market. Considering the bidirectional causality observed between ICTP and institutional quality in the regions (SSA, MENA, and ESAP), it is crucial for policies in these regions to prioritise the establishment of transparent and accountable institutions. These institutions should promote fair competition, safeguard intellectual property rights, and ensure data privacy and security within the ICT sector. Such measures will encourage investment in ICT infrastructure and services while fostering trust and confidence among users. As these regions lag behind in ICT development, policies should also focus on building human capital in ICT to fully leverage its potential for institutional development. Governments should invest in digital skills training programs for both the general population and public officials, enhancing their capacity to utilise and benefit from ICT effectively. (3) Policies should further focus on maximising the benefits of ICT and promoting its widespread adoption for institutional development in ECA and the American regions. Taking into account the other control variables incorporated into estimationsit is suggested in this study that global and regional governments, as well as policymakers, could accelerate the achievement of institutional quality by strategically harnessing the potential of technology penetration.

Our research plays a crucial role in informing the strategic development of ICT policies aimed at promoting quality and inclusive institutions at both global and regional levels. It underscores the significance of incorporating ICTP as a critical factor in effectively achieving institutional quality. Further/future research should investigate whether the conclusions established in this study hold true in particular country-specific or other economic blocs settings and income groups of countries. This would contribute to a deeper understanding of the research topic and provide more relevant policy implications for specific countries, economic blocs, and income groups of countries.

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Competing interests

The authors have declared that no competing interest exists.

Authors' contributions

C.S.S., O.O.D. and T.P.V. contributed equally to this work.

Ethical considerations

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Data availability

Data are available from the corresponding author, C.S.S., under reasonable request.

Disclaimer

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