Institutional development in an information-driven economy: can ICTs enhance economic growth for low- and lower middle-income countries?

Rudra P. Pradhan[a,*], Mak B. Arvin[b], Mahendhiran Nair[c], John H. Hall[d] and Sara E. Bennett[e]

[a]Vinod Gupta School of Management, Indian Institute of Technology, Kharagpur, India;

[b] Department of Economics, Trent University, Peterborough, Canada;

[c]Institute of Global Strategy & Competitiveness and Sunway University Business School, Sunway University, Bandar Sunway, Malaysia;

[d] Department of Financial Management, University of Pretoria, Pretoria, Republic of South Africa; e College of Business, University of Lynchburg, Lynchburg, VA, USA

* CONTACT Rudra P. Pradhan. Vinod Gupta School of Management, Indian Institute of Technology, Kharagpur, West Bengal 721302, India. Email: rudrap@vgsom.iitkgp.ernet.in

ABSTRACT

The information and communication technology (ICT) revolution has brought positive spill-over effects on institutions and economies across the globe, but it has also increased the information gaps between countries. A key characteristic that may explain these widening gaps is the deepening endogenous relationships between ICT infrastructure, institutions of governance, and economic growth in many developing countries. Thus far, the links between these variables have not been discernible in developing economies, so few studies have explored them. In this paper, we investigate the possible Granger causal relationships among institutional quality, economic growth, and ICT infrastructure development for a sample of developing countries for the period from 2005 to 2019. The application of a vector error-correction model reveals strong inter-relationships between all the variables in the short run. In the long run, institutional quality and ICT infrastructure development stimulate economic growth. These complex relationships are explored and lessons are drawn for policymakers.

RESEARCH HIGHLIGHTS

- We assess interactions between institutional quality and ICT infrastructure as well as economic growth.
- We deploy a panel Granger causality test for low- and lower middle-income countries from 2005 to 2019.
- We show that there is Granger causality between the variables in the short and the long term.
- For each case and specification, there is support for the hypothesis that ICT infrastructure and institutional quality both Granger-cause growth in the economy.

- In the short run, we note a *feedback* relationship between institutional quality and economic growth. Other short-run results are more varied, based on the particulars proxies for institutional quality and ICT infrastructure.

Keywords: Institutional quality; economic growth; ICT infrastructure

JEL CLASSIFICATION: O11; O14; O33; O43

1. Introduction and background

Information and communication technology (ICT) has transformed the global economy significantly in recent decades. It has played a key role in enabling economic agents to increase their reach for information, knowledge, resources, and markets. Technology has played a main role in enhancing the productivity and efficiency of firms and the labor force – thus improving the richness of products and services. ICT is therefore often seen as a development tool to help less developed economies to catch up with more developed economies.

For example, in the early 1960s, Singapore was a poor country with few natural resources. By the 1990s, Singapore transformed itself into a high-technology and knowledge-based economy, underpinned by strong institutional governance, supported by a sound ICT strategic plan. In 2019, Singapore was recognized as the most globally digitally connected society, with a competitive economy and one of the highest standards of living in the world (IMD, 2020). This evolution can be ascribed to a series of structural changes undertaken to transform the nation into a digitally connected society with efficient and transparent institutions of governance.

Extensive literature shows that effective governance institutions are critical for sustained economic growth. According to Acemoglu et al. (2005), 'economic institutions determine the incentives of and the constraints on economic actors, and shape economic outcomes.' Effectively, institutions play a central role in the structures governing areas such as property rights, freedom (both political and economic), law and order, regulations, corruption levels, and the quality of the bureaucracy. Research has shown that strong institutional quality in a country can play an important role in economic growth (see, for example, Acemoglu et al., 2005; Acemoglu et al., 2008; Bénassy-Quéré et al., 2007; La Porta et al., 1997; Law et al., 2013; Levchenko, 2007). As property rights on investments increase, the risk of the appropriation of investor wealth (either by governments or by firms) decreases significantly, which may prompt more investment in a given country (Bénassy-Quéré et al., 2007; La Porta et al., 2000).

Technology can streamline multiple layers of institutional governance, improving coordination between different government agencies, industries, community organizations, and other stakeholders. Increased ICT diffusion has led to the emergence of new governance models such as e-government and other digital governance systems. These new governance systems have improved public sector efficiency, enhanced transparency and accountability among civil servants, ensured timely delivery of services, and mitigated risks associated with rent-seeking behavior (Chung, 2015; Nair, 2011). New governance systems and better institutions have contributed to higher consumer and investor confidence, thus propelling economic growth.

Another strategic element of economic development is investment in infrastructure.[1] Increasingly, many traditional infrastructures are being transformed into ‘intelligent infrastructures’ that are connected to digital systems. These intelligent infrastructures provide ‘real-time’ information on the state of the infrastructure in delivering efficient, quality, and transparent services. For example, smart infrastructures not only reduce traffic congestion, pollution and accidents, but also play a key role in mitigating risks associated with Covid-19 or future health pandemics. ICT has also transformed healthcare services in many countries with the incorporation of the Internet of Things (IOT). These new technologies have transformed healthcare systems to provide more effective services, especially to those in the rural and remote areas via telemedicine systems (Baker et al., 2017).

The above examples show that ICT infrastructure development is a key catalyst for deepening the impact of other infrastructure on economic growth. The impact of ICT infrastructure on economic growth is through different channels, which include the following: ICT development increases the demand for the goods and/or services needed to produce ICT infrastructure; ICTs decrease transaction costs due to better communications; they increase productivity, and improve the quality of decision-making. ICTs have various spillovers and externalities, as Roller and Waverman (2001), Romer (1990) and Vu (2011) point out. ICT infrastructure has an increasing and deep impact on traditional infrastructure because it enhances the ability to track real-time information and provide high-quality services to economic agents. ICT has resulted in the emergence of smart transportation systems, smart factories, intelligent buildings and a host of other new innovations that improve the efficacy and quality of services of traditional infrastructure. Small developing economies such as Malaysia are capitalizing on ICT to transform their transportation system, healthcare, cities and other socioeconomic drivers, in order to become globally competitive (Academy of Sciences Malaysia, 2020).

Considered separately, there is considerable evidence that institutional quality and ICT infrastructure have a beneficial effect on economic growth.[2] Given these relationships, it seems logical to consider whether there is a relationship between ICT infrastructure on the one hand, and institutional quality on the other. Arguably, ICT infrastructure and institutional quality may have a deepening impact on each other. For instance, ICT infrastructure might be useful in increasing transparency and thereby reducing corruption in governments through various e-government ICT initiatives (see, for example, Bhatnagar & Singh, 2010; Kim et al., 2009; Lio et al., 2011; Shim & Eom, 2008). Moreover, ICT infrastructure, through e-government systems, provides opportunities to enhance government service delivery, administrative management and citizen engagement. These opportunities generally improve accountability and therefore institutional quality. Good institutional governance should ensure that adequate investments are channeled towards providing greater digital connectivity. Finally, in theory, ICT infrastructure can have a positive impact on political freedom of expression and democracy, as well as access to government services, which would in turn influence government accountability positively, and eventually improve institutional quality (Asongu & Nwachukwu, 2016; Shirazi, 2008). However, it should be noted that internet filtering in countries with less political freedom can limit this relationship (Shirazi et al., 2010).

The relationships between economic growth and institutional quality and those between economic growth and ICT infrastructure have already been extensively studied. By contrast, while the relationship between ICT infrastructure and institutional quality has not been studied to the same degree, considerable attention has been paid to this relationship. Perhaps the more interesting question is how these three variables relate to each other simultaneously. That is, what is the simultaneous dynamic relationship between economic growth, ICT infrastructure, and institutional quality in the short run and the long run? Some studies (discussed below) have considered this question, but there is limited formal evidence on this simultaneous relationship.

Zergawu et al. (2020) consider the effect of both institutional quality and infrastructure (including ICT infrastructure) on economic growth for a pool of 120 countries. Their sample includes countries in different stages of development (from least developed to developed), as well as with different levels of income, ranging from low-income countries (LICs) to high-income countries (HICs). The results show that the interaction terms between infrastructure and institutional quality contribute significantly to positive economic growth. Maiorano and Stern's research (2007) investigated regulatory institutions, mobile telecom penetration, and economic growth for 30 LICs and middle-income countries (MICs); they report a positive impact on economic growth. In a study of 182 countries, Andonova and Diaz-Serrano (2009) show that institutions play an important role (although this is not as strong a role as was thought previously) in telecommunication services – and subsequently on economic growth.

The current study aims to use robust econometric analysis to assess the endogenous relationship between economic growth, ICT infrastructure, and institutional quality. Specifically, we consider the direction of causality that may exist between these variables in both the short and long run.[3] Therefore, our primary objective is to illuminate the roles played by ICT infrastructure and institutional quality in promoting and sustaining strong, vibrant economies. The contribution of the present study is four-fold. Firstly, there is relatively little research specifically on the relationship between ICT infrastructure and institutional quality, so the present study fills that gap. Secondly, as noted in the discussion above, the three variables have not been studied together fully and the present study addresses this aspect. Thirdly, while a few papers have considered this relationship for a broad panel (in terms of the development and income level) of countries, this study focuses on low-income countries (LICs) and lower middle-income countries (LMICs). Although these countries are hardly homogenous in terms of their ICT infrastructure or institutional quality, they do share some similar traits, especially along the lines of economic development and potential for significant growth. Research by Majeed and Ayub found that emerging and developing economies appear to benefit more from increased ICT investment than their developed counterparts, supporting the notion that developing countries may gain the opportunity to 'leapfrog' through ICT. Finally, the results of the current study lead to numerous unique policy implications that these countries should consider to bolster the rate of economic growth and development.

The remainder of the paper is structured into four more sections. In Section 2, we present the empirical literature on the relationships between the variables of interest. We also present the hypotheses to be tested in this work. In Section 3, we detail the methodology that we use to capture the endogenous relationships between institutional quality, ICT infrastructure and economic growth. Section 4 offers the empirical results of the study. Section 5 offers a discussion and sets out the policy implications based on the empirical results.

2. Literature and hypothesis development

The theoretical grounds of and the empirical interactions between institutional quality, ICT infrastructure, and economic growth have been studied individually, but the current study fills the lacuna in the literature on the endogenous and dynamic relationships between all three variables using a robust econometric approach. We acknowledge from the outset that the complex relationships between knowledge spillovers arising from institutional quality and ICT infrastructure to economic growth are probably not uniform across the short and long term.

Moreover, it is important to identify whether any links depend on the choice of the proxies used to capture the three variables. The latter issues have profound policy implications for ensuring sustainable economic growth and are taken up later in the paper. For now, the balance of this section considers what the literature offers regarding possible links between institutional quality, ICT infrastructure, and economic growth.

2.1. Economic growth and ICT infrastructure links

The first part of the literature considers the bond between ICT infrastructure and economic growth, where possible Granger causality between these two variables can be summarized in three diverse ways.

First, the *ICT infrastructure-led economic growth hypothesis* posits that ICT infrastructure Granger-causes economic growth. Those who support this proposition claim that ICT infrastructure contributes to economic growth by promoting productivity and efficiency, and adds to the consumption of cost-effective agents because there is better access to various resources, including knowledge as a resource and commodity, and to the markets. In most countries, ICT infrastructure spending is regarded as a Keynesian fiscal stimulus measure to stimulate economic growth. These arguments are presented, for example, by Colecchia and Schreyer (2002), Dutta (2001), Jorgenson and Vu (2016), Pradhan et al. (2015), Roller and Waverman (2001), Pradhan et al. (2021a, b), and Shiu and Lam (2008).

Second, conversely, the *economic growth-led ICT infrastructure hypothesis* posits that economic growth Granger-causes improved ICT infrastructure. This hypothesis presupposes that, as the GDP climbs, so does the demand for ever more advanced ICT systems and infrastructure. Where enterprises and economic agents attain greater wealth and extend their productivity and eventually their market reach, they begin to demand more sophisticated ICT services. Inevitably, then, the required ICT infrastructure has to keep pace. Studies on this topic have been done by, for example, Beil et al. (2005), Pradhan et al. (2020a, b), Lee et al. (2012), Pradhan et al. (2016), and Shiu and Lam (2008).

Third, a number of studies indicate the reciprocal reinforcement of ICT infrastructure and economic development, offering support for the *feedback hypothesis.* In this case, it is argued, when the economy grows, there is additional demand for ICT infrastructure. The increased ICT infrastructure then in turn drives further economic growth. Some studies on this topic include those of Arvin et al. (2021), Arvin and Pradhan (2014), Cronin et al. (1991), Pradhan et al. (2014), Pradhan et al. (2015), Pradhan et al. (2020a, b), Sarangi and Pradhan (2020), and Zahra et al. (2008).

Based on these three schools of thought, we test the subsequent hypothesis:

> $H_1^{A,B}$: ICT infrastructure Granger-causes (and has a positive impact on) economic growth, and vice versa.

2.2. Institutional quality and links to economic growth

As with the relationship between ICT infrastructure and economic growth, the possible relationship between a country's institutional quality and its economic growth has been researched fairly extensively. The potential Granger causality between institutional quality and economic growth has generated three broad hypotheses.

First, the *institutional quality-led economic growth hypothesis* posits that institutional quality Granger-causes economic growth. The transmission mechanism for this linkage is that high-quality institutions tend to allocate resources optimally to enhance the economic value for all stakeholders in the economy. A robust institutional governance system incorporates continuous reviews, refinements and improvements in the governance systems to ensure that the best technology, talent, incentives and other support systems are in place to create a vibrant and business-friendly economic environment. Some studies on this topic are, for example, those by Afonso and Jalles (2016), Butkiewicz and Yanikkaya (2006), Haini (2020), Hayat (2019), Nawaz et al. (2014), and Nirola and Sahu (2019).

Second, the *economic growth-led institutional quality hypothesis* considers economic growth to Granger-cause institutional quality. The particular hypothesis supports the view that, when countries' economic wealth grows, they have to draw on institutional resources to gain access to the necessary proficiency, the technology, and the wider systems to strengthen the institutions of governance that are already in place, and to help emergent institutions to mature. Institutions of this nature are important catalysts in managing the risks that have been associated with market failures, such as rent-seeking behavior, moral hazards, or a multitude of other negative externalities that can be obstacles to economic growth. It seems that countries with greater economic growth tend to invest in their institutions to offer all stakeholders better returns on their investment and to add value to the economy. A few studies on this topic are those of Burkhart and Lewis-Beck (1994), and Helliwell (1994).

Third, in line with the *feedback hypothesis*, the literature suggests that institutional quality and economic development can indeed reinforce one another; see, for instance, Chong and Calderón (2000), Dawson (2003), Law and Azman-Saini (2012), and Law et al. (2013).

Based on these three schools of thought, we test the following hypothesis:

> $H_2^{a,B}$: Institutional quality Granger-causes (and has a positive role on) economic growth and vice versa.

2.3. ICT infrastructure and institutional quality links

As noted in the introduction, some studies maintain that ICT infrastructure and institutional quality jointly affect economic development (Andonova & Diaz-Serrano, 2009; Maiorano & Stern, 2007; Zergawu et al., 2020). Given this discourse, it is likely that there are some links specifically between ICT infrastructure and institutional quality. That said, there is little formal research specifically on the relationships between these two variables. We can identify the third strand of literature as those studies that consider the link between ICT infrastructure and institutional quality. Once again, the possible Granger causality between the two variables can be summarized in three different ways.

First, the *ICT infrastructure-led institutional quality hypothesis* argues that ICT infrastructure should Granger-cause institutional quality. The advocates of this hypothesis maintain that ICT infrastructure access is of critical importance for improving institutional governance from several perspectives. Many of the development challenges faced by individual countries are multidimensional, requiring cooperation among multiple agencies and stakeholders to address a multitude of challenges. These complex relationships cannot be managed using traditional governance systems, because doing so will lead to fragmentation of policy formulation and implementation. To ensure efficacy in policy formulation, ICT is critical to keep decisionmakers connected and to help them to acquire real-time information to make informed and coordinated decisions. Digital platforms also enable governments to assess the impact of the implemented strategies and take remedial action quickly. It seems that the application ICTs in the public sector via e-government and e-procurement systems and, more recently, blockchain technology will mitigate some of the risks associated with rent-seeking and moral hazards. Furthermore, ICT is also increasingly becoming a key medium for disseminating information to the general public and obtaining feedback to improve service quality.

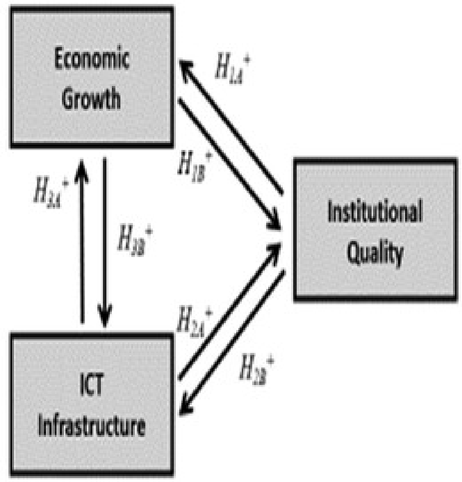
Second, an *institutional quality-led ICT infrastructure hypothesis* claims that institutional quality may in fact Granger-cause growth in ICT infrastructure. The proponents of this hypothesis propose that, as governments improve their governance systems, they need to allocate resources to investments that promise significant multiplier and spillover effects on economic agents and the broader economy. Key investments include the development of a modern and advanced ICT infrastructure that will improve efficiency as well as productivity in the private and public sectors. Some of these investments are the provision of government services via virtual channels to promote service access and supply to businesses, citizens, and other stakeholders – all achievable through electronic government[4] – which will lead to higher ICT infrastructure development.

Third, a *feedback hypothesis* regarding the ICT infrastructure–institutional quality nexus holds that both these variables Granger-cause each other. Some research providing evidence of a relationship between institutional quality and ICT infrastructure includes studies by Entele (2021), Jung (2020), Asongu and Nwachukwu (2016), Nair and Shariffadeen (2009), Shirazi (2008), Lee and Levendis (2006), and West (2004).

Based on these three schools of thought, we test the following hypothesis:

> $H_3^{A,B}$: ICT infrastructure Granger-causes (and has a positive impact on) institutional quality and vice versa.

Figure 1 provides a synopsis of the three hypotheses, including a set of proxy variables that could capture institutional quality and ICT infrastructure, as well as their pathways. The proxy variables are discussed in more detail in the next section.



***Note*:** The hypotheses tested are the following:

H_{1A}^{+}: Institutional quality (positively) Granger-causes economic growth.

H_{1B}^{+}: Economic growth (positively) Granger-causes institutional quality.

H_{2A}^{+}: ICT infrastructure (positively) Granger-causes economic growth.

H_{2B}^{+}: Economic growth (positively) Granger-causes ICT infrastructure.

H_{3A}^{+}: ICT infrastructure (positively) Granger-causes institutional quality.

H_{3B}^{+}: Institutional quality (positively) Granger-causes ICT infrastructure.

Figure 1. Framework of the Causal Pathway between Institutional Quality, ICT Infrastructure, and Economic Growth ***Note:*** The hypotheses tested are the following: $H1_A^+$: Institutional quality (positively) Granger-causes economic growth. $H1_B^+$: Economic growth (positively) Granger-causes institutional quality. $H2_A^+$: ICT infrastructure (positively) Granger-causes economic growth. $H2_B^+$: Economic growth (positively) Granger-causes ICT infrastructure. $H3_A^+$: ICT infrastructure (positively) Granger-causes institutional quality. $H3_B^+$: Institutional quality (positively) Granger-causes ICT infrastructure.

3. Data, variables, and estimation processes

As demonstrated, although the interactions between our variables of interest have been studied at length, there is some disagreement regarding the directions of the causal relationships. In addition, the literature is largely silent on the simultaneous relationships between institutional quality, ICT infrastructure, and economic growth. Many studies use cross-sectional frameworks to study the impact of either institutional quality or ICT infrastructure on economic growth. The current study uses panel data Granger causality tests to investigate the dynamics between the three variables simultaneously. Using data covering a long time span illuminates both the short-term and long-term interactions that may occur among these variables, inclusive of those between institutional quality and ICT infrastructure. The decision to explore all three variables simultaneously is supported by the fact that this research design will be helpful in answering relevant policy demands concerning sustainable economic growth, such as:

- What impact do policies directed at promoting economic growth have in the presence of ICT infrastructure, and vice versa?

- What impact do policies encouraging economic growth have in the presence of institutional quality, and vice versa?
- What is the impact of policies that improve ICT infrastructure in the support of higher institutional quality, and vice versa?

Our study is based on a sample of 79 LICs and LMICs during the period from 2005 to 2019. We use the World Bank classification of these countries; Appendix A provides a list of the countries. The study uses data series from the World Bank's *World Development Indicators* (WDI) database and the World Bank's *Country Policies and Institutional Assessment* (CPIA) database. The variables used in the present study relate to ICT infrastructure (ICT), institutional quality (INQ), and economic growth (PCG).

Table 1 provides a full definition of all the variables. The ICT variable used in the study is comprised of six ICT infrastructure variables, as well as a composite index (CIC). The six ICT variables selected for the study are mobile phones (MOB), telephone landlines (TEL), internet servers (INS), internet users (INU), fixed broadband (FIB), and automated teller machines (ATM).

Table 1. List of Variables.

Variable Acronym	Variable Description
TEL	'**Telephone landlines**': telephone mainlines per 1000 members of the population.
MOB	'**Mobile phones**': mobile phone subscribers per 1000 members of the population.
INS	'**Internet servers**': internet servers per 1000 members of the population.
INU	'**Internet users**': internet users per 1000 members of the population.
FIB	'**Fixed broadband**': fixed broadband per 1000 members of the population.
ATM	'**Automated teller machine**': automated teller machines per 1000 members of the population.
CIC	Composite index of ICT infrastructure, combining *TEL*, *MOB*, *INS*, *INU*, *FIB*, and *ATM* – derived by the authors on the basis of principal component analysis (PCA).
CBH	'**CPIA building human resources rating**': 'the national policies and public and private sector service delivery'.
CBR	'**CPIA business regulatory environment rating**': 'the extent to which the legal, regulatory, and policy environments help or hinder private businesses in investing, creating jobs, and becoming more productive'.
CEM	'**CPIA economic management**': 'macroeconomic management, fiscal policy, and debt policy'.
CMM	'**CPIA macroeconomic management**': 'the monetary, exchange rate, and aggregate demand policy framework'.
CPM	'**CPIA public sector management and institutions**': 'property rights and rule-based governance, quality of budgetary and financial management, efficiency of revenue mobilization, quality of public administration, and transparency, accountability, and corruption in the public sector'.
CQB	'**CPIA quality of budgetary and financial management rating**': 'quality of budgetary and financial management … including timely and accurate accounting and fiscal reporting, including timely and audited public accounts'.
CQP	'**CPIA quality of public administration rating**': 'the extent to which civilian central government staff is structured to design and implement government policy and deliver services effectively'.
CTA	'**CPIA transparency, accountability, and corruption in the public sector**': 'the extent to which the executive can be held accountable for its use of funds and the results of its actions by the electorate and by the legislature and judiciary'.
CIQ	Composite index of institutional quality, combining *CBH, CBR, CEM, CMM, CPM, CQB, CQP*, and *CTA* – derived by the authors on the basis of PCA.
PCG	'**Per capita economic growth**': percentage change in real per capita gross domestic product.

Note: For more comprehensive definitions of the above variables, see the World Bank's *WDI* database and *CPIA* database.

The INQ variable includes eight different institutional qualities and a composite index (CIQ). These eight institutional quality indicators are the CPIA building human resources rating (CBH), the CPIA business regulatory environment rating (CBR), the CPIA economic management cluster average rating (CEM), the CPIA macroeconomic management rating (CMM), the CPIA public sector management as well as institutions cluster average (CPM), the CPIA quality of budgetary as well as financial management rating (CQB), the CPIA quality of public administration rating (CQP), and the CPIA transparency, accountability, and corruption in the public sector rating (CTA).

The study deploys principal component analysis (PCA) to derive both CIC and CIQ. The motivation for using PCA is that it brings together the set of different indicators for ICT infrastructure (and then separately for institutional quality) into a single variable. Appendices B and C provide insight into the PCA. Tables B.1 and C.1 supply econometrics information from the PCA, while Figures B.1-B.2 and C.1-C.2 provide the variable loading strategies from our PCA for the building of the two composite indices.

For the purposes of the study, we measured all monetary variables in constant 2000 US dollars. We then convert all variables into their natural logarithms for our assessment to normalize the data. Table D.1 in Appendix D sets out the descriptive statistics for the variables.

Our study looks at seven specifications, with nine cases under each specification. Each of the seven is based on the seven ICT infrastructure indicators, namely TEL, MOB, INS, INU, FIB, ATM, and the composite measure, CIC. The nine cases are grounded on the nine indicators of institutional quality, namely CBH, CBR, CEM, CMM, CPM, CQB, CQP, CTA, and CIQ. Since institutional quality cannot likely be captured by a single variable, we use nine different indicators to represent it. Arvin et al. (2021) and Nair et al. (2020) have emphasized the importance of using a broad spectrum of institutional quality indicators in studies.

The literature on endogenous growth comments on how *ICT infrastructure* can stimulate economic growth, or the inverse (Pradhan et al., 2014; Pradhan et al., 2020a,b), or presents a theoretical position (Cronin et al., 1991). We have already explained the possible transmission mechanism(s) between these two variables, in a theoretical context. Notwithstanding, there is a lacuna in the empirical literature on how institutional quality can influence the relationship between ICT infrastructure and economic growth. In this paper, we adopt a more *unified* framework to revisit the nexus of ICT infrastructure, institutional quality, and economic growth.

In line with Zergawu et al. (2020), Maiorano and Stern (2007), and Esfahani and Ramırez (2003), in this paper it is assumed that the relationship between these three variables is characterized by the following general production function:

$$\mathrm{PCG} = \mathrm{f}\,(\mathrm{ICT}, \mathrm{INQ}) \tag{1}$$

where *ICT* refers to information and communication technology, *INQ* is institutional quality, and *PCG* is per capita GDP.

Using the general function above, we implement the following dynamic panel regression empirical model to study Granger causal relationships across ICT infrastructure, institutional quality and economic growth. What differentiates our set of equations below from Equation [1] is that we allow all variables to be treated endogenously and to be determined simultaneously in a dynamic setting. We believe that the empirical model which we adopt is appropriate to capture the relationship between the variables that may be intricately linked over time – in both the short and long run.

$$\Delta PCG_{it} = \lambda_{1k} + \varphi_{1i} ECT_{it-1} + \sum_{j=1}^{p} \delta_{1ij} \Delta PCG_{it-j} + \sum_{j=1}^{q} \eta_{1ij} \Delta INQ_{it-j} + \sum_{j=1}^{r} \mu_{1ij} \Delta ICT_{it-j} + \psi_{1it} \tag{2}$$

$$\Delta INQ_{it} = \lambda_{2k} + \varphi_{2i} ECT_{it-1} + \sum_{j=1} \delta_{2ij} \Delta INQ_{it-j} + \sum_{j=1} \eta_{2ij} \Delta PCG_{it-j} + \sum_{j=1}^{r} \mu_{2ij} \Delta ICT_{it-j} + \psi_{2it} \tag{3}$$

$$\Delta ICT_{it} = \lambda_{3k} + \varphi_{3i} ECT_{it-1} + \sum_{j=1} \delta_{3ij} \Delta ICT_{it-j} + \sum_{j=1} \eta_{3ij} \Delta INQ_{it-j} + \sum_{j=1}^{r} \mu_{3ij} \Delta PCG_{it-j} + \psi_{3it} \tag{4}$$

where i represents the country and t refers to the year in the panel; Δ is the first difference operator and ψ is the random error term. *PCG* indicates per capita economic growth. Institutional quality *(INQ)* is defined as CBH, CBR, CEM, CMM, CPM, CQB, CQP, CTA, or CIQ. ICT infrastructure *(ICT)* encompasses MOB, TEL, INS, INU, FIB, ATM, or CIC.

The lag lengths for the differenced variables in the three equations are denoted by p, q and r, respectively. They can be strongminded using the Engle-Granger approach. We use the lagged error-correction term (ECT_{-1}) to embody the long-run dynamics; in the study, differenced variables capture the short-run dynamics across the variables.

4. Estimation results

In order to identify causal linkages between ICT infrastructure, institutional quality and economic growth, we first examined the unit root and nature of stationarity of the data series. We employed the Im-Pesaran-Shin (IPS) test[5] to identify the order of integration of the variables. From the estimated results, the null hypotheses of a unit root and stationarity were rejected at a 1% significance level for the first difference (see Table D.1, Appendix D). Hence, all the data series used in this study for PCG, INQ and ICT were of order one, denoted by I [1]. The Pedroni panel cointegration test was then performed to reveal whether there is cointegration among the covariates. Based on these cointegration results (namely trace statistics and eigen values), the null hypotheses of no cointegration and the no-long-run relationships between the three covariates were rejected at the 1% and 5% significance levels, respectively (see Table D.2, Appendix D). This suggests the existence of cointegration and implies that a long-run relationship exists among ICT infrastructure, institutional quality and economic growth. This is true in our seven specifications, and nine cases under each specification (see Table D.2).

The particular findings confirm the usefulness of the panel VECM approach to identify potential Granger causal relationships among the three variables. The results of panel VECM for seven specifications and nine cases for our sample countries are presented in Table 2.

The first major finding is related to long-run Granger causality. This was determined by an examination of the statistical significance of the ECT_{-1} coefficients. For ΔPCG, the coefficients for the lagged ECTs were statistically significant at significance levels of $p \leq 0.01$. This suggests that per capita economic growth tends to converge to its long-run equilibrium path in reaction to alterations in both institutional quality and ICT infrastructure. This applies to all seven specifications and nine cases in each specification considered. Therefore, it can be concluded that economic growth in LICs and LMICs is significantly influenced by both ICT infrastructure and institutional quality. This finding is robust and implies that, if long-run economic growth is to be stimulated, it is vital to promote institutional quality and ICT infrastructure in these countries.

By contrast, the short-run findings are less consistent. The short-run Granger causality results between the three covariates are summarized in Table 3, which reveals that the short-run adjustment dynamics vary across the seven specifications and nine cases in each specification that we study.

From Table 3, which displays the nexus between institutional quality and economic growth, it is clear that 56 out of 63 cases backing the *feedback hypothesis*, indicating that institutional quality and economic growth Granger cause each other. The finding is not consistent across every instance, but the fact that it holds for 89% of the instances is strong evidence in favor of the feedback hypothesis.

Regarding the link between ICT infrastructure and economic growth, nine out of 63 cases support the *ICT infrastructure-led economic growth hypothesis*, 16 support the *economic growth-led ICT infrastructure hypothesis*, and 36 support the *feedback hypothesis*, indicating that ICT infrastructure Granger-causes economic growth, and vice versa.

Ultimately, in five out of 63 cases, the relationship between institutional quality and ICT infrastructure support the *ICT infrastructure-led institutional quality hypothesis*, 39 cases support the *institutional quality-led ICT infrastructure hypothesis*, 14 cases backing the *feedback hypothesis*, and in five cases Granger causal relationships could be discerned between ICT infrastructure and institutional quality.

Clearly, complex causal links can be demonstrated between the variables in the short term, even though these causal links are not consistently uniform, and occasionally depend on the definition of institutional quality and ICT infrastructure. The most significant finding is the telling short-run nexus between institutional quality and ICT infrastructure, which offers most of the evidence. At the same time, all the dynamics in the longer horizon confirm the particular finding that institutional quality and ICT infrastructure both propel economic growth.

We also performed some supplementary assessments to validate our results.

First, we obtained both fully modified ordinary least squares (FMOLS) and dynamic ordinary least squares (DOLS) estimates, with a demonstration across the board that both institutional quality and ICT infrastructure have significant positive effects on economic growth. This finding is congruent with the results stated by Entele (2021) and Zergawu et al. (2020). The

Table 2. Empirical Results of Panel Granger Causality Test.

Dependent variable	Independent variables and ECT$_{-1}$											
Specification 1: PCG, INQ, TEL												
	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔTEL	ECT$_{-1}$	ΔPCG	ΔCBR	ΔTEL	ECT$_{-1}$	ΔPCG	ΔCEM	ΔTEL	ECT$_{-1}$
ΔPCG	-----	22.4*	0.65	-0.723*	-----	5.62**	0.93	-0.551*	-----	8.88*	1.22	-0.58*
ΔINQ	30.6*	-----	2.06	-0.176	4.44***	-----	4.97***	-0.135	4.96***	-----	7.03**	-0.06
ΔTEL	9.62*	5.70**	-----	-0.344	10.6*	4.56***	-----	-0.22	11.6*	1.7	-----	-0.23
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔTEL	ECT$_{-1}$	ΔPCG	ΔCPM	ΔTEL	ECT$_{-1}$	ΔPCG	ΔCQB	ΔTEL	ECT$_{-1}$
ΔPCG	-----	14.2*	1.32	-0.57*	-----	11.2*	1.72	-0.58*	-----	9.38*	0.91	-0.51*
ΔINQ	10.6*	-----	8.32*	-0.13	8.71*	-----	0.81	-0.08*	39.4*	-----	0.9	-0.36
ΔTEL	12.5*	5.73*	-----	-0.23	11.6*	7.02**	-----	-0.19	10.2*	5.10***	-----	-0.11
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔTEL	ECT$_{-1}$	ΔPCG	ΔCTA	ΔTEL	ECT$_{-1}$	ΔPCG	ΔCIQ	ΔTEL	ECT$_{-1}$
ΔPCG	-----	4.55***	1.24	-0.56*	-----	7.78**	2.81	-0.56*	-----	33.7*	1.46	-0.59*
ΔINQ	5.17***	-----	4.60***	-0.05	5.22***	-----	1.2	-0.09	14.3*	-----	3.09	-0.08
ΔTEL	12.7*	5.34**	-----	-0.24	11.6*	4.27***	-----	-0.23	12.2*	4.79***	-----	-0.21
Specification 2: PCG, INQ, MOB												
	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔMOB	ECT$_{-1}$	ΔPCG	ΔCBR	ΔMOB	ECT$_{-1}$	ΔPCG	ΔCEM	ΔMOB	ECT$_{-1}$
ΔPCG	-----	17.6*	10.7*	-0.60*	-----	8.14*	17.5*	-0.39*	-----	8.23*	17.8*	-0.43*
ΔINQ	20.0*	-----	1.31	-0.28	0.47	-----	2.85	-0.04	4.99***	-----	9.58*	-0.01
ΔMOB	2.59	4.94***	-----	-0.09	29.5*	5.16***	-----	-0.52	27.1*	5.54***	-----	-0.52
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔMOB	ECT$_{-1}$	ΔPCG	ΔCPM	ΔMOB	ECT$_{-1}$	ΔPCG	ΔCQB	ΔMOB	ECT$_{-1}$
ΔPCG	-----	6.57*	16.8*	-0.43*	-----	19.3*	15.3*	-0.56*	-----	23.3*	12.1*	-0.59*
ΔINQ	4.45***	-----	6.53**	-0.04	6.08*	-----	4.37***	-0.06	28.6*	-----	1.69	-0.32
ΔMOB	27.4*	2.34	-----	-0.52	18.6*	6.93*	-----	-0.51	11.7*	4.46***	-----	-0.38
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔMOB	ECT$_{-1}$	ΔPCG	ΔCTA	ΔMOB	ECT$_{-1}$	ΔPCG	ΔCIQ	ΔMOB	ECT$_{-1}$
ΔPCG	-----	3.66***	17.6*	-0.53*	-----	3.67***	17.5*	-0.45*	-----	22.9*	13.5*	-0.53*
ΔINQ	37.1*	-----	3.43***	-0.14	1.75	-----	1.14	-0.03	7.38*	-----	1.46	-0.05
ΔMOB	24.6*	7.08**	-----	-0.53	24.7*	4.30***	-----	-0.52	23.2*	14.3*	-----	-0.53

(*Continued*)

Table 2. Continued.

Dependent variable	Independent variables and ECT_{-1}											
Specification 3: PCG, INQ, INU												
	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔINU	ECT_{-1}	ΔPCG	ΔCBR	ΔINU	ECT_{-1}	ΔPCG	ΔCEM	ΔINU	ECT_{-1}
ΔPCG	-----	24.1*	5.40**	-0.32*	-----	4.10***	4.97***	-0.21*	-----	8.69*	5.92**	-0.17*
ΔINQ	38.9*	-----	9.04*	-0.34	1.59	-----	1.98	-0.04	1.92	-----	0.76	-0.03
ΔINU	1.08	6.59**	-----	-0.22	33.3*	5.43***	-----	-0.12	33.5*	4.35***	-----	-0.12
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔINU	ECT_{-1}	ΔPCG	ΔCPM	ΔNU	ECT_{-1}	ΔPCG	ΔCQB	ΔINU	ECT_{-1}
ΔPCG	-----	6.44*	5.46**	-0.17*	-----	24.4*	5.14**	-0.31*	-----	22.7*	6.36*	-0.37*
ΔINQ	5.76**	-----	0.81	-0.02	4.47**	-----	2.41	-0.05	16.3*	-----	1.18	-0.26
ΔINU	33.5*	5.32***	-----	-0.11	31.6*	5.69**	-----	-0.13	20.7*	7.38*	-----	-0.12
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔINU	ECT_{-1}	ΔPCG	ΔCTA	ΔINU	ECT_{-1}	ΔPCG	ΔCIQ	ΔINU	ECT_{-1}
ΔPCG	-----	6.40*	5.38*	-0.19*	-----	5.64**	4.53***	-0.24*	-----	24.6*	5.54*	-0.20*
ΔINQ	10.9*	-----	4.30***	-0.02	1.73	-----	4.57***	-0.08	4.18***	-----	0.85	-0.04
ΔINU	34.1*	2.83	-----	-0.12	33.8*	4.56***	-----	-0.13	36.8*	5.62**	-----	-0.13
Specification 4: PCG, INQ, INS												
	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔINS	ECT_{-1}	ΔPCG	ΔCBR	ΔINS	ECT_{-1}	ΔPCG	ΔCEM	ΔINS	ECT_{-1}
ΔPCG	-----	21.5*	1.74	-0.51*	-----	15.6*	2.19	-0.50*	-----	12.2*	2.71	-0.53*
ΔINQ	5.10**	-----	5.10**	-0.21	12.6*	-----	4.27***	-0.22	11.3*	-----	1.99	-0.17
ΔINS	7.21*	6.15**	-----	-0.15	6.07**	3.77***	-----	-0.14	10.2*	4.59***	-----	-0.18
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔINS	ECT_{-1}	ΔPCG	ΔCPM	ΔINS	ECT_{-1}	ΔPCG	ΔCQB	ΔINS	ECT_{-1}
ΔPCG	-----	14.2*	3.27	-0.52*	-----	14.4*	4.45***	-0.51*	-----	7.42*	3.22	-0.41*
ΔINQ	10.6*	-----	0.58	-0.25	14.2*	-----	1.13	-0.11	30.7*	-----	1.94	-0.47
ΔINS	11.3*	5.20***	-----	-0.21	10.6*	5.94*	-----	-0.22	9.25*	4.14***	-----	-0.2
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔINS	ECT_{-1}	ΔPCG	ΔCTA	ΔINS	ECT_{-1}	ΔPCG	ΔCIQ	ΔINS	ECT_{-1}
ΔPCG	-----	10.0*	3.38***	-0.48*	-----	5.46**	3.34	-0.48*	-----	4.92***	4.10***	-0.49*
ΔINQ	17.7*	-----	3.16	-0.33	4.22***	-----	2.59	-0.02	18.7*	-----	0.28	-0.17
ΔINS	13.5*	2.1	-----	-0.24	14.0*	4.44***	-----	-0.23	13.0*	5.59*	-----	-0.26

Specification 5: PCG, INQ, FIB

	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔFIB	ECT_{-1}	ΔPCG	ΔCBR	ΔFIB	ECT_{-1}	ΔPCG	ΔCEM	ΔFIB	ECT_{-1}
ΔPCG	-----	29.5*	4.66***	-0.09*	-----	11.8*	4.02***	-0.29*	-----	7.57*	4.42***	-0.36*
ΔINQ	15.2*	-----	1.74	-0.32	4.89***	-----	3.28	-0.13	7.70**	-----	2.72	-0.11
ΔFIB	3.97***	5.63**	-----	-0.61	4.79***	5.25**	-----	-0.11	3.11	5.66*	-----	-0.11
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔFIB	ECT_{-1}	ΔPCG	ΔCPM	ΔFIB	ECT_{-1}	ΔPCG	ΔCQB	ΔFIB	ECT_{-1}
ΔPCG	-----	12.1*	4.99***	-0.36*	-----	9.48*	6.61*	-0.33*	-----	14.0*	5.27*	-0.26*
ΔINQ	5.75**	-----	0.8	-0.12	19.2*	-----	2.04	-0.14	36.8*	-----	0.75	-0.43
ΔFIB	3.61	8.16*	-----	-0.13	3.59	4.88***	-----	-0.1	0.91	5.28***	-----	-0.33
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔFIB	ECT_{-1}	ΔPCG	ΔCTA	ΔFIB	ECT_{-1}	ΔPCG	ΔCIQ	ΔFIB	ECT_{-1}
ΔPCG	-----	7.60*	5.05***	-0.29*	-----	9.64*	4.42***	-0.30*	-----	34.9*	5.12**	-0.31*
ΔINQ	54.8*	-----	0.16	-0.31	4.80***	-----	4.03***	-0.14	29.2*	-----	1.02	-0.15
ΔFIB	0.59	5.43***	-----	-0.05	5.89**	0.62	-----	-0.13	2.57	4.83***	-----	-0.81

Specification 6: PCG, INQ, ATM

	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔATM	ECT_{-1}	ΔPCG	ΔCBR	ΔATM	ECT_{-1}	ΔPCG	ΔCEM	ΔATM	ECT_{-1}
ΔPCG	-----	19.1*	5.38**	-0.53*	-----	13.9*	4.94***	-0.60*	-----	13.9*	3.64	-0.56*
ΔINQ	21.2*	-----	3.04	-0.25	10.4*	-----	1.49	-0.22	6.41*	-----	3.6	-0.09
ΔATM	15.6*	3.66	-----	-0.43	19.5*	0.59	-----	-0.62	17.6*	3.32	-----	-0.68
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔATM	ECT_{-1}	ΔPCG	ΔCPM	ΔATM	ECT_{-1}	ΔPCG	ΔCQB	ΔATM	ECT_{-1}
ΔPCG	-----	13.1*	4.30***	-0.60*	-----	16.8*	4.95***	-0.58*	-----	34.8*	5.78**	-0.53*
ΔINQ	2.99	-----	3.76	-0.08	10.3*	-----	1.97	-0.09	30.9*	-----	6.78**	-0.37
ΔATM	19.2*	3.57***	-----	-0.69	19.8*	6.06**	-----	-0.68	17.6*	0.78	-----	-0.56
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔATM	ECT_{-1}	ΔPCG	ΔCTA	ΔATM	ECT_{-1}	ΔPCG	ΔCIQ	ΔATM	ECT_{-1}
ΔPCG	-----	12.7*	4.50***	-0.60*	-----	27.6*	5.33**	-0.57*	-----	16.6*	6.63**	-0.56*
ΔINQ	47.2*	-----	4.65***	-0.19	3.08	-----	1.88	-0.1	16.3*	-----	1.53	-0.08
ΔATM	18.4*	4.01***	-----	-0.65	22.9*	4.29***	-----	-0.7	11.0*	4.96***	-----	-0.68

(*Continued*)

Table 2. Continued.

Dependent variable	Independent variables and ECT_{-1}											
Specification 7: PCG, INQ, CIC												
	Case 1 (CBH)				Case 2 (CBR)				Case 3 (CEM)			
	ΔPCG	ΔCBH	ΔCIC	ECT_{-1}	ΔPCG	ΔCBR	ΔCIC	ECT_{-1}	ΔPCG	ΔCEM	ΔCIC	ECT_{-1}
ΔPCG	-----	20.2*	9.59*	-0.60*	-----	13.9*	15.3*	-0.69*	-----	8.89*	18.2*	-0.71*
ΔINQ	19.9*	-----	6.00**	-0.27	11.1*	-----	3.04	-0.18	5.52**	-----	9.14*	-0.06
ΔCIC	3.12	10.4*	-----	-0.17	7.48*	12.6*	-----	-0.24	7.42*	8.75*	-----	-0.24
	Case 4 (CMM)				Case 5 (CPM)				Case 6 (CQB)			
	ΔPCG	ΔCMM	ΔCIC	ECT_{-1}	ΔPCG	ΔCPM	ΔCIC	ECT_{-1}	ΔPCG	ΔCQB	ΔCIC	ECT_{-1}
ΔPCG	-----	7.67*	17.0*	-0.71*	-----	23.5*	16.5*	-0.72*	-----	25.9*	13.6*	-0.68*
ΔINQ	5.06***	-----	1.81	-0.04	6.86*	-----	7.29*	-0.07	27.1*	-----	2.98	-0.33
ΔCIC	8.33*	9.36*	-----	-0.25	9.04*	4.34***	-----	-0.26	7.16**	5.69**	-----	-0.23
	Case 7 (CQP)				Case 8 (CTA)				Case 9 (CIQ)			
	ΔPCG	ΔCQP	ΔCIC	ECT_{-1}	ΔPCG	ΔCTA	ΔCIC	ECT_{-1}	ΔPCG	ΔCIQ	ΔCIC	ECT_{-1}
ΔPCG	-----	12.6*	15.1*	-0.70*	-----	14.6*	18.1*	-0.70*	-----	23.9*	15.3*	-0.70*
ΔINQ	32.3*	-----	3.19	-0.19	1.43	-----	1.49	-0.05	9.57*	-----	0.95	-0.08
ΔCIC	6.85*	8.06*	-----	-0.24	9.84*	2.39	-----	-0.27	6.85*	4.68***	-----	-0.23

Note 1: INQ is used as a proxy for CBH, CBR, CEM, CMM, CPM, CQB, CQP, CTA, and CIQ.
Note 2: Variables are defined in Table 1.
Note 3: ECT_{-1} serves as the lagged error-correction term.
Note 4: *, ** and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3. Summary of Short-run Granger Causality Results between INQ, ICT, and PCG.

Specifications	Cases	Causality Inferences between the Variables		
		INQ and PCG	ICT and PCG	INQ and ICT
1	1	CBH ↔ PCG	TEL ← PCG	CBH → TEL
	2	CBR ↔PCG	TEL ← PCG	CBR ↔ TEL
	3	CEM ↔ PCG	TEL ← PCG	CEM ← TEL
	4	CMM ↔ PCG	TEL ← PCG	CMM ↔ TEL
	5	CPM ↔ PCG	TEL ← PCG	CPM → TEL
	6	CQB ↔ PCG	TEL ← PCG	CQB → TEL
	7	CQP ↔ PCG	TEL ← PCG	CQP ↔ TEL
	8	CTA ↔ PCG	TEL ← PCG	CTA → TEL
	9	CIQ ↔ PCG	TEL ← PCG	CIQ → TEL
2	1	CBH ↔ PCG	MOB → PCG	CBH → MOB
	2	CBR → PCG	MOB ↔ PCG	CBR → MOB
	3	CEM ↔ PCG	MOB ↔ PCG	CEM ↔ MOB
	4	CMM ↔ PCG	MOB ↔ PCG	CMM ← MOB
	5	CPM ↔ PCG	MOB ↔ PCG	CPM ↔ MOB
	6	CQB ↔ PCG	MOB ↔ PCG	CQB → MOB
	7	CQP ↔ PCG	MOB ↔ PCG	CQP ↔ MOB
	8	CTA → PCG	MOB ↔ PCG	CTA → MOB
	9	CIQ ↔ PCG	MOB ↔ PCG	CIQ → MOB
3	1	CBH ↔ PCG	INU → PCG	CBH ↔ INU
	2	CBR → PCG	INU ↔ PCG	CBR → INU
	3	CEM → PCG	INU ↔ PCG	CEM → INU
	4	CMM ↔ PCG	INU ↔ PCG	CMM → INU
	5	CPM ↔ PCG	INU ↔ PCG	CPM → INU
	6	CQB ↔ PCG	INU ↔ PCG	CQB → INU
	7	CQP ↔ PCG	INU ↔ PCG	CQP ← INU
	8	CTA → PCG	INU ↔ PCG	CTA ↔ INU
	9	CIQ ↔ PCG	INU ↔ PCG	CIQ → INU
4	1	CBH ↔ PCG	INS ← PCG	CBH ↔ INS
	2	CBR ↔ PCG	INS ← PCG	CBR ↔ INS
	3	CEM ↔ PCG	INS ← PCG	CEM → INS
	4	CMM ↔ PCG	INS ← PCG	CMM → INS
	5	CPM ↔ PCG	INS ↔ PCG	CPM → INS
	6	CQB ↔ PCG	INS ← PCG	CQB → INS
	7	CQP ↔ PCG	INS ↔ PCG	CQP ∤ INS
	8	CTA ↔ PCG	INS ← PCG	CTA → INS
	9	CIQ ↔ PCG	INS ↔ PCG	CIQ → INS
5	1	CBH ↔ PCG	FIB ↔ PCG	CBH → FIB
	2	CBR ↔ PCG	FIB ↔ PCG	CBR → FIB
	3	CEM ↔ PCG	FIB → PCG	CEM → FIB
	4	CMM ↔ PCG	FIB → PCG	CMM → FIB
	5	CPM ↔ PCG	FIB → PCG	CPM → FIB
	6	CQB ↔ PCG	FIB → PCG	CQB → FIB
	7	CQP ↔ PCG	FIB → PCG	CQP → FIB
	8	CTA ↔ PCG	FIB ↔ PCG	CTA ← FIB
	9	CIQ ↔ PCG	FIB → PCG	CIQ → FIB
6	1	CBH ↔ PCG	ATM ↔ PCG	CBH ∤ ATM
	2	CBR ↔ PCG	ATM ↔ PCG	CBR ∤ ATM
	3	CEM ↔ PCG	ATM ← PCG	CEM ∤ ATM
	4	CMM ↔ PCG	ATM ↔ PCG	CMM → ATM
	5	CPM ↔ PCG	ATM ↔ PCG	CPM → ATM
	6	CQB ↔ PCG	ATM ↔ PCG	CQB ← ATM
	7	CQP ↔ PCG	ATM ↔ PCG	CQP ↔ ATM
	8	CTA → PCG	ATM ↔ PCG	CTA → ATM
	9	CIQ ↔ PCG	ATM ↔ PCG	CIQ → ATM
7	1	CBH ↔ PCG	CIC → PCG	CBH ↔ CIC
	2	CBR ↔ PCG	CIC ↔ PCG	CBR → CIC
	3	CEM ↔ PCG	CIC ↔ PCG	CEM ↔ CIC
	4	CMM ↔ PCG	CIC ↔ PCG	CMM → CIC
	5	CPM ↔ PCG	CIC ↔ PCG	CPM ↔ CIC
	6	CQB ↔ PCG	CIC ↔ PCG	CQB → CIC
	7	CQP ↔ PCG	CIC ↔ PCG	CQP → CIC
	8	CTA → PCG	CIC ↔ PCG	CTA ∤ CIC
	9	CIQ ↔ PCG	CIC ↔ PCG	CIQ → CIC

Note 1: INQ is used as a proxy for CBH, CBR, CEM, CMM, CPM, CQB, CQP, CTA, and CIQ.
Note 2: ICT is used as a proxy for TEL, MOB, INU, INS. FIB, ATM, and CIC.
Note 3: Variables are defined in Table 1.
Note 4: ←/ →/↔ arrow**s** indicate the direction of Granger causality, and ∤ denotes non-Granger causality.

results from these empirical approaches are available in Tables D.3 and D.4, respectively (see Appendix D).

Second, we used the generalized forecast error variance decomposition approach to assess the strength of any possible causal link between ICT infrastructure, institutional quality and economic growth. This method has several commonly acknowledged advantages, including the fact that it is not sensitive to how the variables are ordered. Furthermore, the method can estimate possible instantaneous effects of shock among the chosen variables; for instance, it estimates varying levels of shock to the economic growth path resulting from institutional quality and ICT infrastructure. This approach provided estimates (available on request) which support the argument that the effects of institutional quality and ICT infrastructure on economic growth persist over a longer horizon.

5. Conclusions and policy implications

This study explores the short- and long-term nexus between institutional quality, ICT infrastructure, and economic growth for LMICs and LICs. The analyses reveal short-run strong endogenous relationships between the three covariates. These suggest that the three variables have a deepening impact on one another in the short run. As the quality of institutions improves, ICT infrastructure development is ramped up, existing economic sectors improve their productivity, and new economic opportunities emerge in the digital economy. These promote countries' potential to improve the trajectory of their long-term economic growth. Hence, the obvious lesson for policymakers is that they should engineer improvements in institutional quality and ICT infrastructure to take benefit from the clear short-run relationships between these variables. Even more fundamentally, institutional quality and ICT infrastructure (no matter how they are defined) should be elevated *together* in the long term, since they so plainly have an impact on economic growth.

Institutional quality improvements entail concerted commitment from governments to the rule of law, with a strong and independent judiciary system, high-quality enforcement of contracts, property rights and shareholder protection, as well as democratic accountability, bureaucratic sophistication and political stability. The establishment of commissions and institutions to fight corruption ('watchdogs') also enhances institutional quality in a country. Nations with unstable institutions tend to be riddled with corruption and to display a weak legal system, and therefore they fail to attract capital, which will in turn slow economic growth.

Given that 50 of the countries in the sample of the present study are in Africa, a study by Borojo and Yushi (2020) is of particular interest: it reports on the effect of institutional quality on the flow of China's foreign direct investment to African nations. The study found that improvements in institutional quality, especially improvements regarding the efficiency of border controls and transport, property rights protection, legal enforcement, an unbiased judiciary and sound business regulations all have a positive and significant influence on the flow of Chinese capital to Africa.

Institutional quality and e-government can also be enhanced by using internet connectivity to render government services, such as tax submission and collection services. Uyar et al. (2021) report that replacing manual transactions in public administration with the e-filing of tax returns (and payments) enhances e-government and tax collection efficiency; it greatly reduces tax evasion, thereby plugging a potential hole in the revenue pipeline. Such an e-filing system can only be implemented in countries with a robust, well-developed ICT infrastructure that gives the country's citizens – even in rural areas – secure access to online government services via the internet, using personal computers, smartphones or other devices. Our empirical findings indicate that developing LICs and LMICs should simultaneously prioritize strengthening their institutional quality and ICT infrastructure to elevate long-run economic growth. It is evident that the right balance between ICT infrastructure development and institutional quality must be struck: insufficient ICT infrastructure will affect economic growth negatively, but so would ICT infrastructure exceeding a certain threshold where institutional quality is too low.

In summary, the empirical analysis highlights the need for governments in LICs and LMICs to put in place a *co-development* framework to ensure that systematic development of the ICT infrastructure, continuous reforms of the institutions of governance, and sound economic growth strategies are pursued to ensure that these countries break away from the poverty trap and achieve sustainable economic growth.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Rudra P. Pradhan is an SAP Fellow and an Associate Professor at Indian institute of Technology Kharagpur, India, where he has been associated with Vinod Gupta School of Management and RCG School of Infrastructure Design and Management. Pradhan is affiliated with various professional journals like Cities, Technological Forecasting and Social Change, Technology in Society, Telecommunications Policy, and Review of Economics and Finance. He is associate editors of Helioyn, International Journal of Innovation and Technology Management, and Journal of Economic Development. He has been a visiting scholar to University of Pretoria, Republic of South Africa and a visiting professor to Asian Institute of Technology, Thailand.

Mak B. Arvin is a Full Professor of Economics at Trent University, Peterborough, Ontario, Canada, where he has been a faculty member for the past 3 6 years. Arvin's research has resulted in over 180 publications in journals, edited volumes, and books. He has served on the editorial board of over a dozen professional journals and is the former Editor-in-Chief of the International Journal of Happiness and Development and the International Journal of Education Economics and Development. Arvin has been a visiting professor to Boston College and a consultant to the IFO Institute for Economic Research, Germany. His latest book is the Handbook on the Economics of Foreign Aid published in 2015 (with Byron Lew).

Mahendhiran Nair is a Full Professor in Econometrics and Pro-Vice Chancellor (Research Engagement & Impact) at Sunway University. He is a Fellow of CPA (Australia) and Fellow of Academy of Sciences Malaysia. He is a member of the National Science Council of Malaysia and High-Tech Council of Malaysia. Mahendhiran leads a research team that studies the impact of ICT and innovation ecosystems on socioeconomic development in emerging countries. He has published his research work in leading international journals and presented in high impact conferences and forums. He has been a subject matter expert on the knowledge economy and innovation ecosystems for government agencies, public policy organisations and 'think-tanks' in Malaysia and the Middle East.

John H. Hall is a Full Professor of Finance and Head of the Department at Department of Financial Management, University of Pretoria, Republic of South Africa. He has been an academic for more than 20 years and has presented numerous papers (some of which has received best paper awards) at national and international conferences. Hall is a South African National Research Foundation rated researcher.

Sara E. Bennett is an Associate Professor of Finance in the School of Business and Economics at Lynchburg College in Lynchburg, VA, USA. Her areas of interest include macroeconomics, financial development, ICT infrastructure, corporate financial management, and financial derivatives. She is the author of several papers and reviews in refereed journals in the area of finance.

Notes

1 There is no single accepted definition of infrastructure. Torrisi notes that two conditions need to be met for classifying something as infrastructure: first, that it is a capital good, and second, that it is a public good (although it does not have to be owned by the public sector to meet this condition).

2 Most of the current research indicates positive relationships, but some studies report negative or no relationships.

3 Throughout our discussion, the construct of causality is used in terms of temporal or statistical sense, based on the definition of causality advanced by Granger.

4 Electronic government development is the level to which the interactive structures of the World Wide Web (WWW) and Internet technologies are recycled to conduct governments' business (West, 2004).

5 This panel unit root test was chosen based on cross-sectional dependency testing which confirms that there is no cross-sectional dependency among the variables.

References

Academy of Sciences Malaysia. (2020). 10-10 Malaysia Science, Technology, Innovation and Economy (MySTIE): Trailblazing the way for prosperity, socioeconomic well-being and global competitiveness. Academy of Sciences Malaysia. Downloaded from: https://www.akademisains.gov.my/10-10-mystie/ on 10 May 2021.

Acemoglu, D., Johnson, S., & Robinson, J. A. (2005). Institutions as a fundamental cause of long-run growth. *Handbook of Economic Growth*, *1*, 385–472. https://doi.org/10.1016/S1574-0684(05)01006-3

Acemoglu, D., Johnson, S., Robinson, J. A., & Yared, P. (2008). Income and democracy. *American Economic Review*, *98*(3), 808–842. https://doi.org/10.1257/aer.98.3.808

Afonso, A., & Jalles, J. T. (2016). Economic performance, government size, and institutional quality. *Empirica*, *43*(1), 83–109. https://doi.org/10.1007/s10663-015-9294-2

Andonova, V., & Diaz-Serrano, L. (2009). Political institutions and telecommunications. *Journal of Development Economics*, *89*(1), 77–83. https://doi.org/10.1016/j.jdeveco.2008.09.006

Arvin, M. B., & Pradhan, R. P. (2014). Broadband penetration and economic growth nexus: Evidence from cross-country panel data. *Applied Economics*, *46*(35), 4360–4369. https://doi.org/10.1080/00036846.2014.957444

Arvin, M. B., Pradhan, R. P., & Nair, M. (2021a). Uncovering interlinks Among ICT connectivity and penetration, trade openness, foreign direct investment, and economic growth: The Case of the G-20 countries. *Telematics and Informatics*, *60*, 101567–25. https://doi.org/10.1016/j.tele.2021.101567

Arvin, M. B., Pradhan, R. P., & Nair, M. S. (2021b). Are there links between institutional quality, government expenditure, tax revenue and economic growth? Evidence from low-income and lower middle-income countries. *Economic Analysis and Policy*, *70*, 468–489. https://doi.org/10.1016/j.eap.2021.03.011

Asongu, S. A., & Nwachukwu, J. C. (2016). The mobile phone in the diffusion of knowledge for institutional quality in sub-saharan Africa. *World Development*, *86*, 133–147. https://doi.org/10.1016/j.worlddev.2016.05.012

Baker, S. B., Xiang, W., & Atkinson, I. (2017). Internet of things for smart healthcare: Technologies, challenges and opportunities. *IEEE Access*, *5*, 26521–26544. https://doi.org/10.1109/ACCESS.2017.2775180

Beil, R. O., Ford, G. S., & Jackson, J. D. (2005). On the relationship between telecommunications investment and economic growth in the United States. *International Economic Journal*, *19*(1), 3–9. https://doi.org/10.1080/1351161042000320399

Bénassy-Quéré, A., Coupet, M., & Mayer, T. (2007). Institutional determinants of foreign direct investment. *The World Economy*, *30*(5), 764–782. https://doi.org/10.1111/j.1467-9701.2007.01022.x

Bhatnagar, S. C., & Singh, N. (2010). Assessing the impact of E-government: A study of projects in India. *Information Technologies & International Development*, *6*(2), 109–127. https://itidjournal.org/index.php/itid/article/download/523/523-1394-2-PB.pdf

Borojo, D. G., & Yushi, J. (2020). The impacts of institutional quality and business environment on Chinese foreign direct investment flow to African countries. *Economic Research-Ekonomska Istraživanja*, *33*(1), 26–45. https://doi.org/10.1080/1331677X.2019.1696691

Burkhart, R. E., & Lewis-Beck, M. S. (1994). Comparative democracy: The economic development thesis. *American Political Science Review*, *88*(4), 903–910. https://doi.org/10.2307/2082715

Butkiewicz, J. L., & Yanikkaya, H. (2006). Institutional quality and economic growth: Maintenance of the rule of law or democratic institutions, or both? *Economic Modelling*, *23*(4), 648–661. https://doi.org/10.1016/j.econmod.2006.03.004

Chong, A., & Calderón, C. (2000). Causality and feedback between institutional measures and economic growth. *Economics and Politics*, *12*(1), 69–81. https://doi.org/10.1111/1468-0343.00069

Chung, C. S. (2015). The introduction of e-government in Korea: Development journey, outcomes and future. *Gestion et Management Public*, *3*(4), 107–122. https://doi.org/10.3917/gmp.034.0107

Colecchia, A., & Schreyer, P. (2002). ICT investment and economic growth in the 1990s: Is the United States a unique case? *Review of Economic Dynamics*, *5*(2), 408–442. https://doi.org/10.1006/redy.2002.0170

Cronin, F. J., Parker, E. B., Colleran, E. K., & Gold, M. A. (1991). Telecommunications infrastructure and economic growth. *Telecommunications Policy*, *15*(6), 529–535. https://doi.org/10.1016/0308-5961(91)90007-X

Dawson, J. (2003). Causality in the freedom-growth relationship. *European Journal of Political Economy*, *19*(3), 479–495. https://doi.org/10.1016/S0176-2680(03)00009-0

Dutta, A. (2001). Telecommunications and economic activity: An analysis of Granger causality. *Journal of Management Information Systems*, *17*(4), 71–95. https://doi.org/10.1080/07421222.2001.11045658

Entele, B. R. (2021). Impact of institutions and ICT services in avoiding resource curse: Lessons from the successful economies. *Heliyon*, *7*(2), e05961. https://doi.org/10.1016/j.heliyon.2021.e05961

Esfahani, H. S., & Ramırez, M. T. (2003). Institutions, infrastructure, and economic growth. *Journal of Development Economics*, *70*(2), 443–477. https://doi.org/10.1016/S0304-3878(02)00105-0

Haini, H. (2020). Examining the relationship between finance, institutions and economic growth: Evidence from the ASEAN economies. *Economic Change and Restructuring*, *53*(4), 519–542. https://doi.org/10.1007/s10644-019-09257-5

Hayat, A. (2019). Foreign direct investments, institutional quality, and economic growth. *The Journal of International Trade & Economic Development*, *28*(5), 561–579. https://doi.org/10.1080/09638199.2018.1564064

Helliwell, J. F. (1994). Empirical linkages between democracy and economic growth. *British Journal of Political Science*, *24*(2), 225–248. https://doi.org/10.1017/S0007123400009790

IMD. (2020). *IMD World Competitiveness Ranking 2020: Showing Strength of Small Economies*, June. Downloaded from https://www.imd.org/news/updates/IMD-2020-World-Competitiveness-Ranking-revealed/ on 10 May 2021.

Jorgenson, D. W., & Vu, K. M. (2016). The ICT revolution, world economic growth, and policy issues. *Telecommunications Policy*, *40*(5), 383–397. https://doi.org/10.1016/j.telpol.2016.01.002

Jung, J. (2020). Institutions and telecommunications investment. *Information Economics and Policy*, *50*, 100849. https://doi.org/10.1016/j.infoecopol.2020.100849

Kim, S., Kim, H. J., & Lee, H. (2009). An institutional analysis of an e-government system for anti-corruption: The case of OPEN. *Government Information Quarterly*, *26*(1), 42–50. https://doi.org/10.1016/j.giq.2008.09.002

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (2000). Investor protection and corporate governance. *Journal of Financial Economics*, *58*(1-2), 3–27. https://doi.org/10.1016/S0304-405X(00)00065-9

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1997). Legal determinants of external finance. *The Journal of Finance*, *52*(3), 1131–1150. https://doi.org/10.1111/j.1540-6261.1997.tb02727.x

Law, S. H., & Azman-Saini, W. N. W. (2012). Institutional quality, governance, and financial development. *Economics of Governance*, *13*(3), 217–236. https://doi.org/10.1007/s10101-012-0112-z

Law, S. H., Lim, T. C., & Ismail, N. W. (2013). Institutions and economic development: A Granger causality analysis of panel data evidence. *Economic Systems*, *37*(4), 610–624. https://doi.org/10.1016/j.ecosys.2013.05.005

Lee, S. H., & Levendis, J. (2006). Creation of a separate telecom agency: A duration analysis of its time pattern. *Contemporary Economic Policy*, *24*(3), 407–417. https://doi.org/10.1093/cep/byj039

Lee, S. H., Levendis, J., & Gutierrez, L. (2012). Telecommunications and economic growth: An empirical analysis of Sub-saharan Africa. *Applied Economics*, *44*(4), 461–469. https://doi.org/10.1080/00036846.2010.508730

Levchenko, A. A. (2007). Institutional quality and international trade. *The Review of Economic Studies*, *74*(3), 791–819. https://doi.org/10.1111/j.1467-937X.2007.00435.x

Lio, M. C., Liu, M. C., & Ou, Y. P. (2011). Can the internet reduce corruption? A cross-country study based on dynamic panel data models. *Government Information Quarterly*, *28*(1), 47–53. https://doi.org/10.1016/j.giq.2010.01.005

Maiorano, F., & Stern, J. (2007). Institutions and telecommunications infrastructure in low and middle-income countries: The case of mobile telephony. *Utilities Policy*, *15*(3), 165–181. https://doi.org/10.1016/j.jup.2007.04.001

Nair, M. (2011). Inclusive innovation and sustainable development: Leap-frogging strategies to a high-income economy. *ICT Strategic Review 2011/*2012, PIKOM and MOSTI, Malaysia, Chapter 11: 225-257.

Nair, M., Pradhan, R. P., & Arvin, M. B. (2020). Endogenous dynamics between R&D, ICT and economic growth: Empirical evidence from the OECD countries. *Technology in Society*, *62*, 101315–12. https://doi.org/10.1016/j.techsoc.2020.101315

Nair, M., & Shariffadeen, T. M. A. (2009). *Managing innovation in the network economy: Lessons for countries in the Asia pacific region, digital Review of Asia 2009-2010*. Sage, 25–42.

Nawaz, S., Iqbal, N., & Khan, M. A. (2014). The impact of institutional quality on economic growth: PanelEvidence. *The Pakistan Development Review*, *53*(1), 15–31. https://doi.org/10.30541/v53i1pp.15-31

Nirola, N., & Sahu, S. (2019). The interactive impact of government size and quality of institutions on economic growth- evidence from the states of india. *Heliyon*, *5*(3), e01352–28. https://doi.org/10.1016/j.heliyon.2019.e01352

Pradhan, R. P., Arvin, M. B., & Nair, M. (2021a). Urbanization, transportation infrastructure, ICT, and economic growth: A temporal causal analysis. *Cities*, *115*, 103213–19. https://doi.org/10.1016/j.cities.2021.103213

Pradhan, R. P., Arvin, M. B., Nair, M., & Bennett, S. E. (2020b). Sustainable economic growth in the European union: The role ofICT, venture capital, and innovation. *Review of Financial Economics*, *38*(1), 34–62. https://doi.org/10.1002/rfe.1064

Pradhan, R. P., Arvin, M. B., Nair, M., Bennett, S. E., & Bahmani, S. (2021b). Some determinants and mechanics of economic growth in middle-income countries: The role of ICT infrastructure development, taxation and other macroeconomic variables. *Singapore Economic Review*, 34–62. https://doi.org/10.1002/rfe.1064

Pradhan, R. P., Arvin, M. B., Nair, M., Hall, J. H., & Bennett, S. E. (2020a). Sustainable economic development in India: The dynamics between financial inclusion, ICT development and economic growth. *Technological Forecasting and Social Change*, *169*, 1–19. https://doi.org/10.1016/j.techfore.2021.120758

Pradhan, R. P., Arvin, M. B., & Norman, N. R. (2015). The dynamics of information and communications technologies infrastructure, economic growth, and financial development: Evidence from Asian countries. *Technology in Society*, *42*(1), 135–149. https://doi.org/10.1016/j.techsoc.2015.04.002

Pradhan, R. P., Arvin, M. B., Norman, N. R., & Bele, S. K. (2014). Economic growth and the development of telecommunications infrastructure in the G-20 countries: A panel-VAR approach. *Telecommunications Policy*, *38*(7), 634–649. https://doi.org/10.1016/j.telpol.2014.03.001

Pradhan, R. P., Arvin, M. B., Norman, N. R., & Bennett, S. E. (2016). Financial depth, internet penetration rates and economic growth: Country-panel evidence. *Applied Economics*, *48*(4), 331–343. https://doi.org/10.1080/00036846.2015.1078450

Roller, L. H., & Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American Economic Review*, *91*(4), 909–923. https://doi.org/10.1257/aer.91.4.909

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*(5, Part 2), S71–S102. https://doi.org/10.1086/261725

Sarangi, A. K., & Pradhan, R. P. (2020). ICT infrastructure and economic growth: A critical assessment and some policy implications. *Decision*, *47*(4), 363–383. https://doi.org/10.1007/s40622-020-00263-5

Shim, D. C., & Eom, T. H. (2008). E-government and anti-corruption: Empirical analysis of international data. *International Journal of Public Administration*, *31*(3), 298–316. https://doi.org/10.1080/01900690701590553

Shirazi, F. (2008). The contribution of ICT to freedom and democracy: An empirical analysis of archival data on the Middle East. *The Electronic Journal of Information Systems in Developing Countries*, *35*(1), 1–24. https://doi.org/10.1002/j.1681-4835.2008.tb00243.x

Shirazi, F., Ngwenyama, O., & Morawczynski, O. (2010). ICT expansion and the digital divide in democratic freedoms: An analysis of the impact of ICT expansion, education and ICT filtering on democracy. *Telematics and Informatics*, *27*(1), 21–31. https://doi.org/10.1016/j.tele.2009.05.001

Shiu, A., & Lam, P. L. (2008). Causal relationship between telecommunications and economic growth in China and its regions. *Regional Studies*, *42*(5), 705–718. https://doi.org/10.1080/00343400701543314

Uyar, A., Nimer, K., Kuzey, C., Shahbaz, M., & Schneider, F. (2021). Can e-government initiatives alleviate tax evasion? The moderation effect of ICT. *Technological Forecasting and Social Change*, *166*, 120597–13. https://doi.org/10.1016/j.techfore.2021.120597

Vu, K. M. (2011). ICT as a source of economic growth in the information age: Empirical evidence from the 1996–2005 Period. *Telecommunications Policy*, *35*(4), 357–372. https://doi.org/10.1016/j.telpol.2011.02.008

West, D. M. (2004). E-Government and the transformation of service delivery and citizen attitudes. *Public Administration Review*, *64*(1), 15–27. https://doi.org/10.1111/j.1540-6210.2004.00343.x

Zahra, K., Azim, P., & Mahmood, A. (2008). Telecommunication infrastructure development and economic growth:A panel data approach. *The Pakistan Development Review*, *47*(4), 711–726. https://doi.org/10.30541/v47i4IIpp.711-726

Zergawu, Y. Z., Walle, Y. M., & Giménez-Gómez, J. M. (2020). The joint impact of infrastructure and institutions on economic growth. *Journal of Institutional Economics*, *16*(4), 481–502. https://doi.org/10.1017/S1744137420000016