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RESEARCH ARTICLE

Estimating the connection of information technology, foreign direct investment, trade, renewable energy and economic progress in Pakistan: evidence from ARDL approach and cointegrating regression analysis

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Abstract
The present study aims to investigate the effects of information and communication technology, foreign direct investment, trade and renewable energy use with GDP growth in Pakistan using time series data ranging from 1985 to 2017. Stationarity of data was verified by using unit root tests including ADF and P-P, while an autoregressive distributed lag (ARDL) model was used to check the dynamic association amid prescribed variables with long- and short-run analysis. Furthermore, cointegrating regression analysis with FMOLS, DOLS and CCR was applied to validate the variables causality. The outcomes during long-run analysis show that ICTE, trade and renewable energy have constructive linkage to GDP growth, while foreign direct investment has adverse influence to GDP growth in Pakistan. Similarly, the outcomes from cointegrating regression technique exposed that all variables including foreign direct investment, ICTE and trade have positive and constructive association with GDP growth except renewable energy that causes the adverse association to GDP growth in Pakistan. On the basis of outcomes, we will discuss the policy recommendations.

Keywords Information technology · Economic growth · Foreign investment · Trade · Energy · ARDL

Introduction

The information and communication technologies (ICTs) have changed the world in which we live tremendously in the past few decades. Someone referred to the reality that ICT plays a key function in social change. ICT not only connects people but also has the potential to maximize commitment, transparency, responsibility and human development (Iqbal et al. 2020; Latif et al. 2018). ICT is able to grow firms' economic prosperity and earnings and to create jobs that have a big impact, which would lead countries to increase expenditure on research and development activities and to the

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introduction of a new ICT system. This deposit has created new ICT innovations and fostered further global economic growth (Nair et al. 2020). Advances in ICT have also brought together many parts of the world that encouraged developing countries to adopt the technology used by developed nations, thus enhancing production and faster economic growth in former countries. In the recent decades, the new information structure has improved and promoted ICT in a better way (Sahoo and Mathiyazhagan 2003; Anitha 2012; Temiz and Gökmen, 2014a, b; Sinha and Sengupta 2019).

Information and telecommunication technology has always played a significant part in economic and social growth. The principle explanation for the social, economic and cultural stagnation in developed countries has now been widely accepted as being that they cannot create, grow and use the best technology in the production operations. The extent and effect of this technology have been one of today's most critical problems in the world and has captured the world's attention (Badri et al. 2019; Lu 2018; Batool et al. 2019). In the foreign development network, the rapid developments in knowledge and communication technologies and growing economic globalization provide new possibilities for developed countries to take part in global output, thereby allowing these countries to enhance their competitiveness. Competitiveness internationally covers not only trade liberalization, but also the growing economic value of the ICT market. Developing economies are also experiencing several obstacles to develop and optimize the advantages of the ICT industries associated with these economies. The ICT sector's characteristics differ from those of the other sectors in the economy, especially as the prices of goods begin to decrease (Fakher 2016; Anwar et al. 2016; Asteriou et al. 2014; Haseeb et al. 2019).

Several studies have emphasised the connection amid economic progress, FDI, urbanization, income inequality, international tourism and human capital decrease (John 2016; Gönel and Aksoy 2016; Tee et al. 2017; Duarte et al. 2017; Sultanuzzaman and Shakij 2018; Masipa 2018; Hammami and Dal Zotto 2020; Samir and Mefteh 2020; Rehman et al. 2021; Alvarado et al., 2021a, b; Rehman et al. 2021; Alvarado et al., 2021a, b), but the primary motive of the present analysis was to demonstrate the association amid gross domestic product growth, ICTE, foreign direct investment, trade and renewable energy in Pakistan. Two unit root test including ADF and the Phillips-Perron (P-P) was utilized to check the variable stationary and series stability, while an autoregressive distributed lag bounds testing approach was employed to verify the variable linkages with long- and short-run causal dynamics. Furthermore, cointegrating regression analysis with FMOLS, DOLS and CCR techniques was also applied to check the variable's association.

In addition to the introduction, the remaining part of the paper is organized as follows: 'Existing literature'deals with the previous literature on the topic, while 'Methods and data' provides data, an econometric approach and unit root tests as well as the ARDL model. The results of various tests were seen in 'Empirical results'. The study conclusion and policy proposals are illustrated in the 'Conclusions and recommendations'.

Existing literature

The production of information and communication technology gives developed countries unique prospects for change in many prospects. It eliminates historical and geographical constraints and makes it possible, as industrialized economies, and in manufacturing and foreign exchange, to perform more effectively. A well-developed information technology infrastructure can contribute to drastically evolving environment for foreign affairs and can improve strategic advantages and enhance socio-economic growth opportunities. The information technology resources may shape an interconnected network between individuals, enterprises and administrations in various economies all over the world. Advanced telecommunication networks need to be established in emerging countries to compete in the dynamic international market and to gain new foreign investment (Avgerou 1998; Bon et al. 2016; Jorgenson and Vu 2016; Niebel 2018). Increased ICT facilities and logistical assistance may influence internal markets and reduce the adverse externalities of ICT instruments. This is one of the reasons which draw FDI directed to exports. Advancement in the technology has also improved accountability and has become the main factor of foreign investment, the path to good governance and the elimination of corruption. In democracies, power sharing is more open than defending property owners' rights and reducing the danger of foreign direct investment, thus enhancing the capacity to fascinate the investment especially in emerging economies (Bankole et al. 2011; Soper et al. 2012; Lindo 2017; Lee et al. 2018).

The exponential rise of ICT in global products and services development impacts all economies and impregnates civilization as a whole. The key motive factors for economic growth by improved production and human advancement are both related to knowledge and communication technologies. Obviously, developments in ICTs have altered the forms of jobs, qualifications, roles and work activities in organizations, agencies and community as well as impacted their efficiency (Badri et al. 2016; Hassan et al. 2019; Kurniawati 2020). Investment now seems to be a crucial element in every country's production and growth. Specifically, a few years back, emerging countries claimed that the weapon used by established countries to regulate their economy was a foreign direct investment. The emergence of globalization and its resulting systemic reforms and foreign law, however, would facilitate economic cooperation and remove the gap between countries that had once crippled trade (Abdouli and Hammami 2017; Sothan 2017; Bermejo Carbonell and Werner 2018).

The standard and effect on financial sector production are thus prerequisites for successful economic progress along with recognition of other economic characteristics. Consequently, the economic growth influence and FDI will rely on the financial sector's development in each region. Indeed, funds from foreign investors cross the financial framework of a nation until it is assigned to the respective economic sectors. In the banking market, direct international investment and economic development are intermediate (Acquah and Ibrahim, 2020; Hossain 2016; Williams 2017; Tahir et al. 2019). Foreign direct investment will improve technology

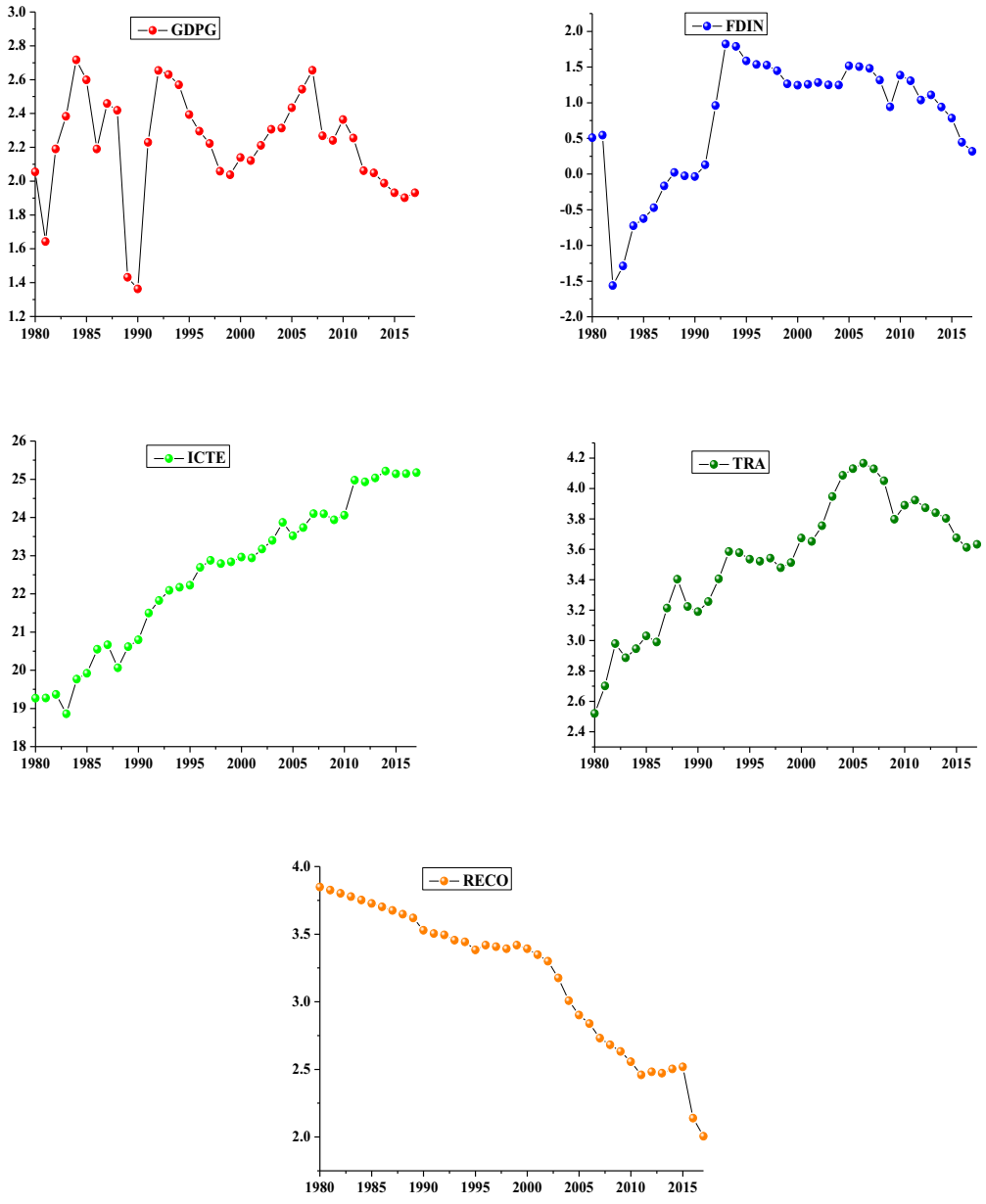

Fig. 1 Plot of variables trends

Table 1 Statistical analysis of the variables

	LnGDPG	LnFDIN	LnICTE	LnTRA	LnRECO
Mean	2.217169	0.752959	22.51438	3.529878	3.183260
Median	2.235034	1.071956	22.85627	3.581090	3.392336
Maximum	2.717286	1.822431	25.21267	4.166338	3.848029
Minimum	1.362799	− 1.562247	18.85894	2.519698	2.005129
Std. Dev.	0.310941	0.864442	1.962029	0.415292	0.525025
Skewness	− 0.789687	− 1.025300	− 0.318139	− 0.506054	− 0.599024
Kurtosis	3.782962	3.196201	1.921249	2.593638	2.107568
Jarque-Bera	4.920127	6.718802	2.483545	1.883367	3.533609
Probability	0.085430	0.034756	0.288872	0.389971	0.170878

transfer and thereby enhance factors' output performance. It is reasonable to assume that technical developments are converted into an improvement in labour efficiency, culminating in an increase in capital production. Given the value of technology and expertise in growing output levels, if economic growth is powered by innovation, it is appropriate for foreign direct investment to boost progress (Azman-Saini et al. 2010; Barro and Lee 2013; Szkorupová 2014).

Appropriate alternatives to different issues are sought of foreign direct investment. FDI offers important resources, technologies and expertise, to support economic growth and development. Moreover, new opportunities across the globe can be more readily obtained by foreign direct investment. In fact, several factors, such as skilled and qualified workforce and productivity, have a significant effect on the recruiting and retention of foreign direct investment (Shaari et al. 2014; Monaghan 2012; Almfraji and Almsafir 2014). The ICTs are one of the key industries that foster economic development in the present age of globalization. It fosters technical advances in digital connectivity and industrial technology and stimulates economic growth and development. Once globalization has started, countries need to strengthen their networks of expertise and exchange in order to provide good stewards for the transfer of information inside and through countries. Globalization is necessary and encouraging the universal and rapid use of ICT systems (Kaware and Sain 2015; Olusanya 2013; Jinadu et al. 2016; Bhujabal and Sethi 2020).

Significantly larger utilization of IT (Information Technology) has lowered communication costs and consequently improved the flow and performance of information. ICT is a sign of technical progress and a central element in developed countries' economic progress (Farhadi et al. 2012; Bertschek et al. 2015; Aghaei and Rezagholizadeh 2017). Trade and investment usually has a beneficial influence on economic development, as it tends to construct physical resources, to generate jobs, to improve potential in production and to strengthen local labour skills. The study finds that increased influxes of FDI in South Asia were connected to the multiple rises in national investors' spending, which indicates that there is a correlation impact between foreign investment and gross domestic product (Agrawal 2000; Li and Liu 2005; Anwar and Nguyen 2010).

Methods and data

An autoregressive distributed lag (ARDL) bounds testing technique with cointegrating regression analysis was used to verify the variable association. All variable time series data were taken from the WDI (https://data.worldbank.org/country/pakistan), and the data range is 1985–2017. Study variables are ICTE, foreign direct investment, trade and renewable energy. The trends of the variables are plotted in Fig. 1.

Table 2 Correlation amid variables

	LnGDPG	LnFDIN	LnICTE	LnTRA	LnRECO
LnGDPG	[1.000000]	0.141654	− 0.046924	0.210191	0.106348
LnFDIN	0.141654	[1.000000]	0.656844	0.708692	− 0.413809
LnICTE	− 0.046924	0.656844	[1.000000]	0.863958	− 0.919851
LnTRA	0.210191	0.708692	0.863958	[1.000000]	− 0.736578
LnRECO	0.106348	− 0.413809	− 0.919851	− 0.736578	[1.000000]

Table 3 Unit root test results

Variables	ADF with trend		ADF without trend		P-P with trend		P-P without trend	
	Test statistic (*P*-values)		Test statistic (*P*-values)		Test statistic (*P*-values)		Test statistic (*P*-values)	
	At level	At first difference	At level	At first difference	At level	At first difference	At level	At first difference
LnGDPG	− 3.771337 (0.0308)	− 4.795109 (0.0030)	− 0.893068 (0.3211)	− 4.795109 (0.0030)	− 2.569726 (0.2954)	− 6.715190 (0.0000)	− 0.309066 (0.5674)	− 6.423744 (0.0000)
LnFDIN	− 1.009590 (0.9280)	− 3.754831 (0.0355)	− 1.287118 (0.1790)	− 1.873686 (0.0591)	− 1.734050 (0.7157)	− 5.346647 (0.0005)	− 1.201529 (0.2060)	− 5.493334 (0.0000)
LnICTE	− 2.693349 (0.2450)	− 2.705926 (0.2418)	2.874368 (0.9986)	− 0.934645 (0.3038)	− 2.686285 (0.2477)	− 17.86302 (0.0000)	4.828698 (1.0000)	− 5.827584 (0.0000)
LnTRA	− 1.370440 (0.8527)	− 5.333731 (0.0006)	0.768871 (0.8753)	− 4.810128 (0.0000)	− 1.340098 (0.8617)	− 5.296478 (0.0006)	1.118453 (0.9287)	− 4.754961 (0.0000)
LnRECO	− 0.668757 (0.9681)	− 3.547078 (0.0542)	− 2.390903 (0.0182)	− 3.274754 (0.0018)	− 0.874245 (0.9484)	− 4.888155 (0.0019)	− 3.185533 (0.0022)	− 3.285949 (0.0017)

Econometric model specification and unit root tests

In order to demonstrate the association amid variables, we can specify the following model as:

$$\mathrm{GDPG_t} = \mathrm{f}(\mathrm{FDIN_t}, \mathrm{ICTE_t}, \mathrm{TRA_t}, \mathrm{RECO_t}) \quad (1)$$

Equation (1) explains that $\mathrm{GDPG_t}$ denotes GDP growth, $\mathrm{FDIN_t}$ is showing foreign direct investment, variable $\mathrm{ICTE_t}$ specifies the information and communication technology, variable $\mathrm{TRA_t}$ illustrates trade in Pakistan and $\mathrm{RECO_t}$ denotes renewable energy consumption. Furthermore, we can also write Eq. (1) as:

$$\mathrm{GDPG_t} = \zeta_0 + \zeta_1 \mathrm{FDIN_t} + \zeta_2 \mathrm{ICTE_t} + \zeta_3 \mathrm{TRA_t} + \zeta_4 \mathrm{RECO_t} + \varepsilon_t \quad (2)$$

Log-linear model can be demonstrated by using logarithmic form of all variables and specified as:

$$\mathrm{Ln(GDPG_t)} = \zeta_0 + \zeta_1 \mathrm{Ln(FDIN_t)} + \zeta_2 \mathrm{Ln(ICTE_t)} + \zeta_3 \mathrm{Ln(TRA_t)} + \zeta_4 \mathrm{Ln(RECO_t)} + \varepsilon_t \quad (3)$$

Equation (3) verifies the logarithmic form all variables including ICTE, FDI, trade and renewable energy. Time measurement is denoted by t, and error term is denoted by ε_t, where ζ_1 to ζ_4 are illustrating the model coefficients.

In addition, all variables with an ARDL model have been tested for the unit root in a stationary manner which can be specified as:

$$\Delta \mathrm{E_t} = \alpha_\circ + \delta_\circ \mathrm{K} + \delta_1 \mathrm{L_{t-1}} + \sum_{i=1}^{m} \beta_1 \Delta \mathrm{L_{t-1}} + \varepsilon_t \quad (4)$$

Equation (4) illustrates the unit root test, where Δ is differential operator.

ARDL model specification to cointegration test

Present analysis followed a research method developed by Pesaran and Shin (1998) for ARDL and continued by Pesaran et al. (2001) further to define the relation entreaty and independent variable with long- and short-run assessments. The cointegration testing method takes place regardless of the order in which the variables I(0) and I(1), rather than I(2), are merged. The *F*-statistical calculation is used for evaluating the co-movement of the long-term regression

Table 4 VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	− 63.22751	NA	3.81e-05	4.013383	4.237848	4.089932
1	93.18000	257.6124*	1.70e-08*	− 3.716470	− 2.369682*	− 3.257177*
2	114.7102	29.12915	2.32e-08	− 3.512367	− 1.043254	− 2.670329
3	144.7371	31.79318	2.28e-08	− 3.808067	− 0.216630	− 2.583284
4	175.2106	23.30326	3.12e-08	− 4.130037*	0.583723	− 2.522510

*Denotes the lag order designated by the criterion

Table 5 Bounds test to cointegration outcomes

ARDL bounds test		
Test statistic	Value	K
F-statistic	7.415524	4
Critical value bounds		
Level of significance	I(0) Bound	I(1) Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

between the research variables of interest. As in uncontrolled with UECM, ARDL model can generally be specified as:

$$\begin{aligned}\Delta \mathrm{LnGDPG}_t = {} & \vartheta_0 + \sum_{i=1}^{u} \vartheta_{1j} \Delta \mathrm{LnGDPG}_{t-1} + \sum_{i=1}^{u} \vartheta_{2j} \Delta \mathrm{LnFDIN}_{t-1} \\ & + \sum_{i=1}^{u} \vartheta_{3j} \Delta \mathrm{LnICTE}_{t-1} + \sum_{i=1}^{u} \vartheta_{4j} \Delta \mathrm{LnTRA}_{t-1} \\ & + \sum_{i=1}^{u} \vartheta_{5j} \Delta \mathrm{LnRECO}_{t-1} + \vartheta_6 \mathrm{LnGDPG}_{t-1} \\ & + \vartheta_7 \mathrm{LnFDIN}_{t-1} + \vartheta_8 \mathrm{LnICTE}_{t-1} + \vartheta_9 \mathrm{LnTRA}_{t-1} \\ & + \vartheta_{10} \mathrm{LnRECO}_{t-1} + \varepsilon_t \end{aligned} \quad (5)$$

where Δ displays a differential operator, u displays the lag order and ε_t is the error expression. Long-run analyses between variables can be defined as:

$$\begin{aligned}\Delta \mathrm{LnGDPG}_t = {} & \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta \mathrm{LnGDPG}_{t-i} \\ & + \sum_{i=1}^{m} \beta_{2i} \Delta \mathrm{LnFDIN}_{t-i} \\ & + \sum_{i=1}^{m} \beta_{3i} \Delta \mathrm{LnICTE}_{t-i} + \sum_{i=1}^{m} \beta_{4i} \Delta \mathrm{LnTRA}_{t-i} \\ & + \sum_{i=1}^{m} \beta_{5i} \Delta \mathrm{LnRECO}_{t-i} + \varepsilon_t \end{aligned} \quad (6)$$

m presents the lag order in the Eq. (6). In an ECM (error correction model), the short-run dynamics between variables are shown in the ARDL technique and specified as:

$$\begin{aligned}\Delta \mathrm{LnGDPG}_t = {} & a_0 + \sum_{i=1}^{f} a_{1i} \Delta \mathrm{LnGDPG}_{t-i} \\ & + \sum_{i=1}^{f} a_{2i} \Delta \mathrm{LnFDIN}_{t-i} + \sum_{i=1}^{f} a_{3i} \Delta \mathrm{LnICTE}_{t-i} \\ & + \sum_{i=1}^{f} a_{4i} \Delta \mathrm{LnTRA}_{t-i} + \sum_{i=1}^{f} a_{5i} \Delta \mathrm{LnRECO}_{t-i} \\ & + \alpha \mathrm{ECM}_{t-1} + \varepsilon_t \end{aligned} \quad (7)$$

Equation (7) shows the short-run dynamic where f denotes the lag order. ARDL approach has been used to monitor the diverse ties between GDP growth, ICTE, FDI, trade and renewable energy use. In respect for acceptance and denial of a null hypothesis, in the upper case, the F values measured are smaller than the prescribed limits. The non cointegration-based theories are dismissed and suggest the cointegrated reliance of interaction and the invaders between variables.

Empirical results

Statistical analysis of variables

Table 1 displays the statistical values of all variables and the statistics from Jarque-Bera, and the probability values prove that the variables are frequently distributed.

Correlation amid variables

Table 2 reports the result of the correlation analysis amid GDP growth, ICTE, FDI, trade and renewable energy; outcomes show that all variables are normally correlated.

Table 6 Cointegration test results

Trace statistics				Maximum eigenvalue statistics			
Hypothesized no. of CE(s)	TS	CV (0.05)	Prob.**	Hypothesized no. of CE(s)	Max-eigen statistic	CV (0.05)	Prob.**
None*	112.0794	69.81889	0.0000	None*	50.54325	33.87687	0.0002
Atmost1	61.53611	47.85613	0.0016	Atmost1	31.68799	27.58434	0.0140
Atmost2	29.84812	29.79707	0.0493	Atmost2	19.90388	21.13162	0.0735
Atmost3	9.944232	15.49471	0.2850	Atmost3	9.135875	14.26460	0.2750
Atmost4	0.808357	3.841466	0.3686	Atmost4	0.808357	3.841466	0.3686

*Indicates the hypothesis rejection at 0.05 level

**Show the *P*-values of MacKinnon-Haug-Michelis (1999)

Unit root test

Table 3 indicates the unit root test outcomes for Augmented Dickey-Fuller (Dickey and Fuller 1981) and Phillips-Perron (Phillips and Perron 1988). Each of the test results revealed that the significance of 1%, 5% and 10% of the variables was not protected by the spectrum of I(2), therefore that the autoregressive distributed lag (ARDL) model was used. Several approaches for cointegration regarding data analysis are presented in the different studies. However, the ARDL model is recommended, because of its numerous advantages, to be stronger and favoured, for instance because not all variables are in the same order in inclusion in the classification. Therefore, because of its simplicity and suitability for models of mixed variables, we chose the ARDL approach for cointegration.

Optimal lag selection

Table 4 illustrates the results of the lag order selection in order to demonstrate the association amid variables.

Bounds test to cointegration

The results of the ARDL limit test are depicted in Table 5. Calculated *F*-statistics surpassed the maximum vital bond, which were 7.415524. The cointegration results show the connection between GDP growth, ICTE, FDI, trade and renewable energy.

The variable robustness was confirmed through long-run association by applying Johansen and Juselius cointegration technique (Johansen and Juselius 1990). Trace test and maxeign statistics indicate the rejection of null hypothesis with having nil cointegration.

Johansen cointegration test

Table 6 reports the outcomes of the cointegration test which indicates the hypothesis rejection at 0.05% level.

Long- and short-run dynamics

Table 7 reports the outcomes of the long- and short-run analysis amid variables with their coefficients and probability values.

Table 7 explains the variables correlation by long- and short-run dynamics. The ECM entails the cointegration amid prescribed variables and presence of short-run analysis and association which used to detain the adjusted measurement. The outcomes via long-run analysis which is illustrated in the Table 7 show that the variables ICTE, trade and renewable energy have constructive coefficients of 0.545437, 0.745343 and 2.072191 with probability values of 0.0769, 0.2280 and 0.0473 correspondingly. During analysis, foreign direct investment exposes an adverse association with GDP growth. The advancement of innovations linked to ICTE has been recognized as the key path to generate further jobs and economic growth. The advancement of information and technology sector has been described as the principal transformer of

Table 7 Long- and short-run estimation

Cointegrating form of variables				
Variable	Coefficient	SE	TS	Prob.
D(FDIN)	0.297216	0.154580	1.922727	0.0714
D(FDIN(-1))	− 0.176863	0.234432	− 0.754431	0.4609
D(FDIN(-2))	0.501544	0.169725	2.955045	0.0089
D(ICTE)	− 0.005987	0.116292	− 0.051484	0.9595
D(TRA)	0.477210	0.423735	1.126200	0.2757
D(TRA(-1))	0.785904	0.536014	1.466201	0.1608
D(TRA(-2))	− 1.829793	0.409642	− 4.466809	0.0003
D(RECO)	0.048830	0.427040	0.114345	0.9103
D(RECO(-1))	1.097154	1.067140	1.028125	0.3183
D(RECO(-2))	− 2.106021	0.987256	− 2.133207	0.0478
CointEq(-1)	− 0.571156	0.127295	− 4.486877	0.0003
Long-run estimation				
LnFDIN	− 0.299300	0.249725	− 1.198519	0.2472
LnICTE	0.545437	0.289634	1.883195	0.0769
LnTRA	0.745343	0.596018	1.250537	0.2280
LnRECO	2.072191	0.968819	2.138883	0.0473
C	− 19.433284	10.175457	− 1.909819	0.0732
Short-run dynamics				
GDPG(-1)	0.428844	0.127295	3.368908	0.0036
FDIN	0.297216	0.154580	1.922727	0.0714
FDIN(-1)	− 0.143481	0.234704	− 0.611330	0.5491
FDIN(-2)	0.176863	0.234432	0.754431	0.4609
FDIN(-3)	− 0.501544	0.169725	− 2.955045	0.0089
ICTE	− 0.005987	0.116292	− 0.051484	0.9595
ICTE(-1)	0.317517	0.121808	2.606694	0.0184
TRA	0.477210	0.423735	1.126200	0.2757
TRA(-1)	− 1.095392	0.529606	− 2.068313	0.0542
TRA(-2)	− 0.785904	0.536014	− 1.466201	0.1608
TRA(-3)	1.829793	0.409642	4.466809	0.0003
RECO	0.048830	0.427040	0.114345	0.9103
RECO(-1)	0.125846	0.597020	0.210790	0.8356
RECO(-2)	− 1.097154	1.067140	− 1.028125	0.3183
RECO(-3)	2.106021	0.987256	2.133207	0.0478
C	− 11.09943	4.640014	− 2.392112	0.0286
Diagnostic tests				
R^2(0.867860)Serial correlation1.991071 (0.1710)				
Adjusted R^2(0.751265)Heteroskedasticity0.435612 (0.5143)				
F-statistic(7.443410)Ramsey RESET1.102795 (0.3030)				
Prob(*F*-statistic)(0.000088)CUSUMStable				
Durbin-Watson stat(2.227357)CUSUMSQStable				

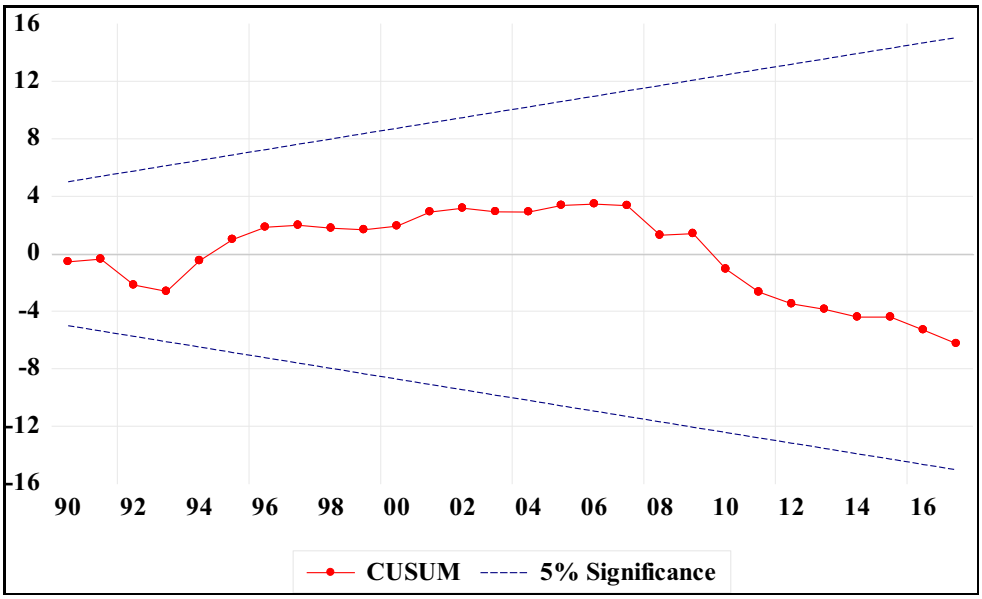

Fig. 2 CUSUM plot

economic operation and foreign exchange. The expanded usage of information and communication technology lowered correspondence costs and eventually enhanced dissemination and construction of evidence. Information technology is a sign of the improvements in innovations and is a significant economic force in developed countries (World Bank 2017; Xing 2018; Stanley et al. 2018; Rath and Hermawan 2019). Information and communication technology influences economic development, including transport, transport, schooling, utilities, entertainment and science information. Information and communication technology promotes international transfers and allocations of ideas and influences all facets of contemporary life. Moreover, as a consequence of the transformation in the information technology market, human growth is experiencing a change in mindset, the phase in widening the multiple options such as schooling, safe living and living standards (Yakunina and Bychkov 2015).

The development of information technology improves the living conditions and standards of the population, shortens distances, shortens travel and trade, creates investment opportunities and provides new workers. The liberalization has quickly expanded wireless carriers, built up information technology networks and allowed major investments to improve the economy. Secondly, Asian countries are presently undergoing highly precarious economic and human development status (Nath and Liu 2017; Zhang 2019). Another

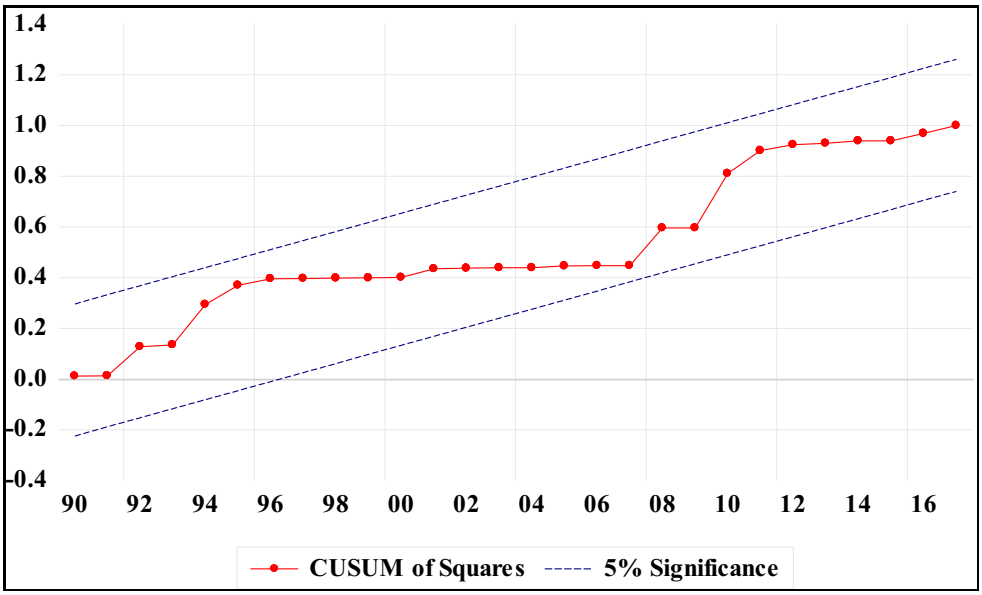

Fig. 3 CUSUM of squares plot

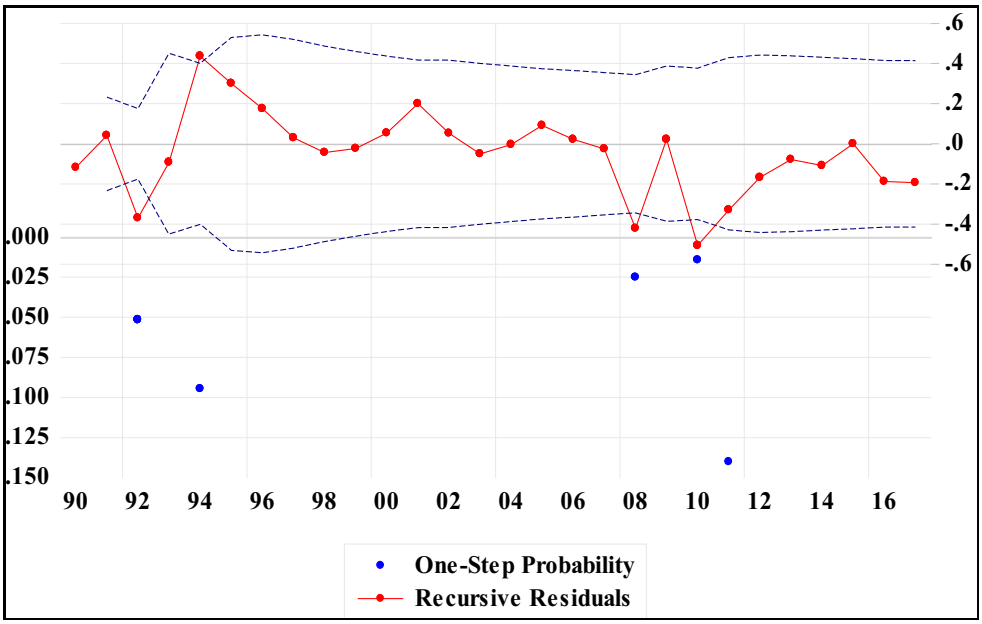

Fig. 4 Plot of one-step forecast test

macroeconomic factor shaping economic growth is the influx of foreign direct investment. It directly impacts the economy by providing valuable tangible and intangible properties such as technologies and its related strands, the formation of resources and the creative capacity. It indirectly boosts global production by promoting investment finance for multiple host markets and creates favourable externalities, integrating new management capabilities in a number of sectors, boosting economic performance by creating high quantities of jobs and the government revenues and financing the current account deficit. This stimulates economic development. Dynamic linkages between industrial growth and foreign direct investment influx are therefore critical for consistent political economic policies (Iamsiraroj and Ulubaşoğlu 2015; Temiz and Gökmen, 2014a, b; Sokhanvar 2019). Plots of CUSUM and CUSUM of squares are showed in the Figs. 2 and 3. Furthermore, Figs. 4 and 5 demonstrate one-step forecast test and N-step forecast test.

Cointegrating regression analysis

The cointegrating regression analysis outcomes are reported in the Table 8 with FMOLS, DOLS, and CCR. The outcomes of Panel A revealed that variables ICTE, FDI and trade have

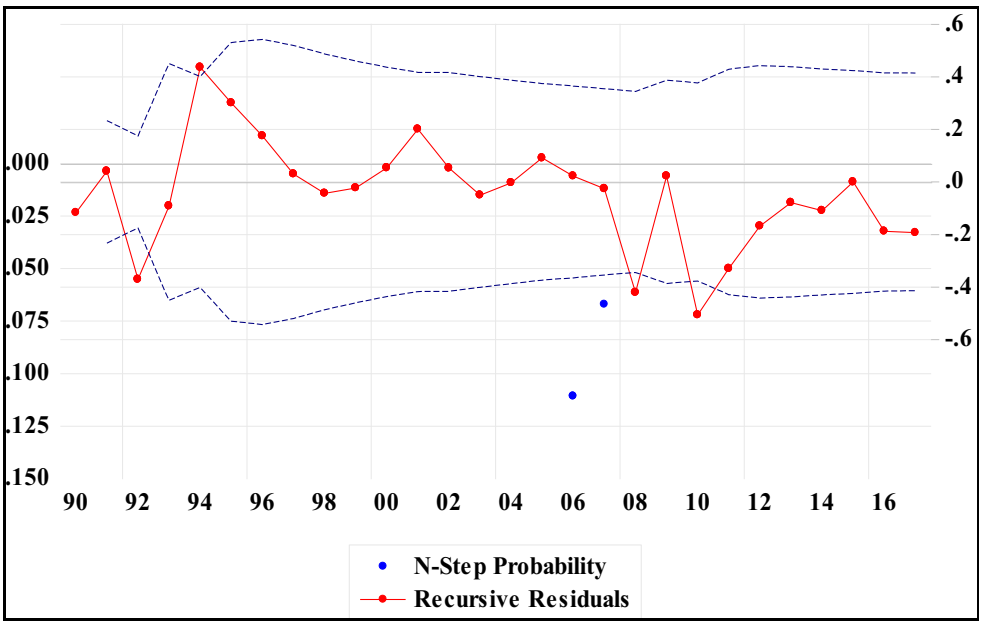

Fig. 5 Plot of N-step forecast test

Table 8 Results of FMOLS, DOLS and CCR

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
Panel A: fully modified least squares (FMOLS)				
LnFDIN	0.114380	0.140128	0.816250	0.4215
LnICTE	0.105218	0.197529	0.532672	0.5986
LnTRA	0.660027	0.296347	2.227213	0.0345
LnRECO	− 0.904960	0.389342	− 2.324330	0.0279
C	1.901072	4.444837	0.427704	0.6723
@TREND	− 0.086381	0.039196	− 2.203831	0.0362
$R^2$0.424358				
Mean dependent var 2.220124				
Adjusted $R^2$0.317758				
S.D. dependent var 0.303271				
S.E. of regression 0.250496				
Sum squared resid 1.694201				
Long-run variance 0.061691				
Panel B: dynamic least squares (DOLS)				
LnFDIN	0.128675	0.444557	0.289445	0.7765
LnICTE	0.225908	0.801579	0.281829	0.7822
LnTRA	0.789708	0.876419	0.901062	0.3828
LnRECO	− 1.560624	1.041359	− 1.498641	0.1562
C	1.664142	18.23875	0.091242	0.9286
@TREND	− 0.130263	0.139194	− 0.935841	0.3652
$R^2$0.664968				
Mean dependent var 2.229143				
Adjusted $R^2$0.258142				
S.D. dependent var 0.303594				
S.E. of regression 0.261489				
Sum squared resid 0.957274				
Long-run variance 0.095378				
Panel C: canonical cointegrating regression (CCR)				
LnFDIN	0.141076	0.163196	0.864456	0.3950
LnICTE	0.057520	0.273845	0.210047	0.8352
LnTRA	0.612357	0.316591	1.934219	0.0636
LnRECO	− 0.934003	0.400969	− 2.329364	0.0276
C	3.072044	6.002034	0.511834	0.6129
@TREND	− 0.078516	0.050601	− 1.551674	0.1324
$R^2$0.416520				
Mean dependent var 2.220124				
Adjusted R^2 0.308468				
S.D. dependent var 0.303271				
S.E. of regression 0.252196				
Sum squared resid 1.717270				
Long-run variance 0.061691				

constructive linkage with GDP growth. Similarly Panel B results exposed that ICTE, foreign direct investment and trade have significant association with GDP growth. Furthermore, Panel C results of canonical cointegrating regression also exposed that the coefficients of foreign direct investment, information and communication technology have constructive association with GDP growth, while the variable renewable energy consumption has adverse influence to GDP growth in Pakistan during all panel analyses. Figure 6 clearly demonstrates the outcomes of Panel A (FMOLS), Panel B (DOLS) and Panel C (CCR) amid prescribed variables linkages.

Conclusions and recommendations

The major aim of this analysis was to check the dynamic association of ICTE, FDI, trade and renewable energy usage with GDP growth in Pakistan by utilizing data series ranging from 1985 to 2017. Data stationarity was verified by applying unit root tests including ADF and P-P, while an ARDL approach was used to check the dynamic association amid study variables with long- and short-run analysis. Furthermore, cointegrating regression analysis with FMOLS, DOLS and CCR was applied to demonstrate the variable causality. The outcomes during long-run analysis show that ICTE, trade and renewable energy have constructive linkage to GDP growth, while foreign direct investment has adverse influence to GDP growth in Pakistan. Similarly, the outcomes of cointegrating regression analysis exposed that all variables including FDI, information and communication technology and trade have positive and constructive association with GDP growth, while in this analysis, renewable energy consumption causes the adverse association to GDP growth in Pakistan.

Foreign direct investment plays a crucial role in emerging economies. FDI frequently contributes to the transition and raise of new technology to the host country. Economists believe that emerging technologies and high-quality management provide for pressures on domestic foreign investment while keeping the sector competitive. Further, external direct intervention, such as labour control and training opportunities, in developing economies, has introduced significant and positive external factors to improve commodity production. On the basis of the results, the Pakistani government needs potential measures to upgrade data technologies to boost economic development. Several policy proposals for the Pakistani government are presented here. In order to draw national and foreign investors to invest in Pakistan, it is necessary to improve the security and insurance schemes. With a view to minimizing domestic production expense, Pakistan can increase final exports

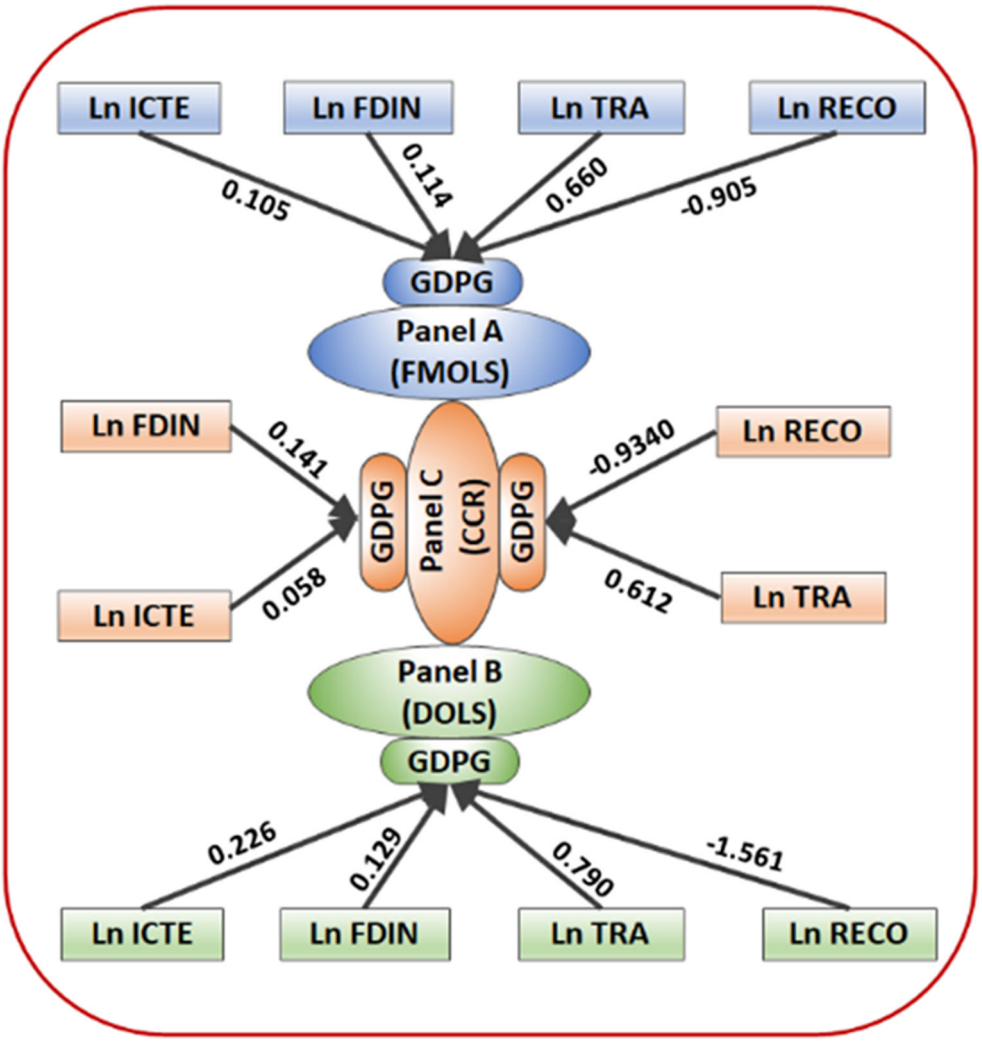

Fig. 6 Dynamic association of variables through FMOLS, DOLS and CCR

by expanding infrastructure, developing new roads, extending transport facilities, and installing advanced machines.

Abbreviations ICT, Information and communication technology; GDP, Gross domestic product; ADF, Augmented Dickey-Fuller; P-P, Phillips-Perron; ARDL, Autoregressive distributed lag; FMOLS, Fully modified least squares; DOLS, Dynamic least squares; CCR, Canonical cointegrating regression; FDI, Foreign direct investment; WDI, World development indicators; UECM, Unrestricted error correction model; ECM, Error correction model; VAR, Vector autoregressive; AIC, Akaike information criterion; LR, Likelihood ratio; FPE, Final prediction error; SC, Schwarz information criterion; HQ, Hannan Quinn

Availability of data and materials Not applicable

Author contribution AR conceived the study, collected the data, designed the econometric methodology and wrote the original draft; IO and MA reviewed and edited the manuscript; HM and CI read and made suggestions to improve the quality of the manuscript. All authors read and approved the final manuscript.

Declarations

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

Competing interests The authors declare no competing interests.

References

Abdouli M, Hammami S (2017) Investigating the causality links between environmental quality, foreign direct investment and economic growth in MENA countries. Int Bus Rev 26(2):264–278

Acquah AM, Ibrahim M (2020) Foreign direct investment, economic growth and financial sector development in Africa. Journal of Sustainable Finance & Investment 10(4):315–334

Aghaei M, Rezagholizadeh M (2017) The impact of information and communication technology (ICT) on economic growth in the OIC Countries. Economic and Environmental Studies 17(42):255–276

Agrawal P (2000) Economic impact of foreign direct investment in South Asia. India and the WTO 117

Almfraji MA, Almsafir MK (2014) Foreign direct investment and economic growth literature review from 1994 to 2012. Procedia Soc Behav Sci 129:206–213

Alvarado R, Deng Q, Tillaguango B, Méndez P, Bravo D, Chamba J, Alvarado-Lopez M, Ahmad M (2021a) Do economic development and human capital decrease non-renewable energy consumption? Evidence for OECD countries. Energy 215:119147

Alvarado R, Tillaguango B, López-Sánchez M, Ponce P, Işık C (2021b) Heterogeneous impact of natural resources on income inequality: the role of the shadow economy and human capital index. Economic Analysis and Policy 69:690–704

Anitha R (2012) Foreign direct investment and economic growth in India. International Journal of Marketing, Financial Services & Management Research 1(8):108–125

Anwar S, Nguyen LP (2010) Foreign direct investment and economic growth in Vietnam. Asia Pacific business review 16(1-2):183–202

Anwar Y, Farooq F, Ullah S, Faheem M (2016) Impact of financial globalization on human capital: evidence from Pakistan. Pakistan Journal of Social Sciences (PJSS) 36(2)

Asteriou D, Dimelis S, Moudatsou A (2014) Globalization and income inequality: a panel data econometric approach for the EU27 countries. Econ Model 36:592–599

Avgerou C (1998) How can IT enable economic growth in developing countries? Inf Technol Dev 8(1):15–28

Azman-Saini WNW, Baharumshah AZ, Law SH (2010) Foreign direct investment, economic freedom and economic growth: international evidence. Econ Model 27(5):1079–1089

Badri AK, Badri AK, Yahyavi R (2016) Examination of the quality of environment in MENA countries with emphasizing using of ICT. Noble International Journal of Social Sciences Research 1(1):11–15

Badri AK, Badri PK, Cham M (2019) ICT and human development in selected devolving countries. International Journal of Social Sciences Perspectives 5(2):30–35

Bankole FO, Shirazi F, Brown I (2011) Investigating the impact of ICT investments on human development. The Electronic Journal of Information Systems in Developing Countries 48(1):1–19

Barro RJ, Lee JW (2013) A new data set of educational attainment in the world, 1950–2010. J Dev Econ 104:184–198

Batool R, Sharif A, Islam T, Zaman K, Shoukry AM, Sharkawy MA, Gani S, Aamir A, Hishan SS (2019) Green is clean: the role of ICT in resource management. Environ Sci Pollut Res 26(24):25341–25358

Bermejo Carbonell J, Werner RA (2018) Does foreign direct investment generate economic growth? A new empirical approach applied to Spain. Econ Geogr 94(4):425–456

Bertschek I, Briglauer W, Hüschelrath K, Kauf B, Niebel T (2015) The economic impacts of broadband internet: a survey. Rev Netw Econ 14(4):201–227

Bhujabal P, Sethi N (2020) Foreign direct investment, information and communication technology, trade, and economic growth in the South Asian Association for Regional Cooperation countries: an empirical insight. J Public Aff 20(1):e2010

Bon A, Akkermans H, Gordijn J (2016) Developing ICT services in a low-resource development context. CSIMQ 9:84–109

Dickey DA, Fuller WA (1981) Likelihood ratio statistics for autoregressive time series with a unit root. Journal of the Econometric Society, Econometrica, pp 1057–1072

Duarte LDRV, Kedong Y, Xuemei L (2017) The relationship between FDI, economic growth and financial development in Cabo Verde. Int J Econ Financ 9(5):132–142

Fakher A (2016) The impact of investment in ICT sector on foreign direct investment: applied study on Egypt. Review of Integrative Business and Economics 5:151–166

Farhadi M, Ismail R, Fooladi M (2012) Information and communication technology use and economic growth. PLoS One 7(11):e48903

Gönel F, Aksoy T (2016) Revisiting FDI-led growth hypothesis: the role of sector characteristics. The Journal of International Trade & Economic Development 25(8):1144–1166

Hammami A, Dal Zotto C (2020) The FDI-economic growth nexus: a human resource management perspective—the case of the ICT sector. ICT for an Inclusive World: Industry 40-Towards the Smart Enterprise 35:327

Haseeb A, Xia E, Saud S, Ahmad A, Khurshid H (2019) Does information and communication technologies improve environmental quality in the era of globalization? An empirical analysis. Environ Sci Pollut Res 26(9):8594–8608

Hassan ST, Xia E, Huang J, Khan NH, Iqbal K (2019) Natural resources, globalization, and economic growth: evidence from Pakistan. Environ Sci Pollut Res 26(15):15527–15534

Hossain S (2016) Foreign direct investment, economic freedom and economic growth: evidence from developing countries. Int J Econ Financ 8(11):200–214

Iamsiraroj S, Ulubaşoğlu MA (2015) Foreign direct investment and economic growth: a real relationship or wishful thinking? Econ Model 51:200–213

Iqbal K, Peng H, Hafeez M (2020) Analyzing the effect of ICT on migration and economic growth in belt and road (BRI) countries. J Int Migr Integr 21(1):307–318

Jinadu O, Ojeka SA, Ogundana OM (2016) IFRS adoption and foreign direct investment: evidence from Nigerian quoted firms. Mediterr J Soc Sci 7(2):99

Johansen S, Juselius K (1990) Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. Oxf Bull Econ Stat 52(2):169–210. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x

John EI (2016) Effect of foreign direct investment on economic growth in Nigeria. European Business & Management 2(2):40–46

Jorgenson DW, Vu KM (2016) The ICT revolution, world economic growth, and policy issues. Telecommun Policy 40(5):383–397

Kaware SS, Sain SK (2015) ICT application in education: an overview. International Journal of Multidisciplinary Approach & Studies 2(1):25–32

Kurniawati MA (2020) The role of ICT infrastructure, innovation and globalization on economic growth in OECD countries, 1996-2017. Journal of Science and Technology Policy Management 11(2):193–215. https://doi.org/10.1108/JSTPM-06-2019-0065

Latif Z, Latif S, Ximei L, Pathan ZH, Salam S, Jianqiu Z (2018) The dynamics of ICT, foreign direct investment, globalization and economic growth: panel estimation robust to heterogeneity and cross-sectional dependence. Telematics Inform 35(2):318–328

Lee GW, Shao B, Vinze A (2018) The role of ICT as a double-edged sword in fostering societal transformations. J Assoc Inf Syst 19(3):1

Li X, Liu X (2005) Foreign direct investment and economic growth: an increasingly endogenous relationship. World Dev 33(3):393–407

Lindo O (2017) A method for estimating the intangible value impact of ICT investments. Revista de Sistemas de Informação 20:10–26

Lu WC (2018) The impacts of information and communication technology, energy consumption, financial development, and economic growth on carbon dioxide emissions in 12 Asian countries. Mitig Adapt Strateg Glob Chang 23(8):1351–1365

Masipa TS (2018) The relationship between foreign direct investment and economic growth in South Africa: vector error correction analysis. Acta Commercii 18(1):1–8. https://doi.org/10.4102/ac.v18i1.466

Monaghan S (2012) Attraction and retention of foreign direct investment (FDI): the role of subnational institutions in a small, highly globalised economy. Ir J Manag 31(2):45

Nair M, Pradhan RP, Arvin MB (2020) Endogenous dynamics between R&D, ICT and economic growth: empirical evidence from the OECD countries. Technol Soc 62:101315

Nath HK, Liu L (2017) Information and communications technology (ICT) and services trade. Inf Econ Policy 41:81–87
Niebel T (2018) ICT and economic growth—comparing developing, emerging and developed countries. World Dev 104:197–211
Olusanya SO (2013) Impact of foreign direct investment inflow on economic growth in a pre and post deregulated Nigeria economy. A granger causality test (1970-2010). Eur Sci J 9:25
Pesaran MH, Shin Y (1998) An autoregressive distributed-lag modelling approach to cointegration analysis. Econometric Society Monographs 31:371–413
Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16(3):289–326
Phillips PC, Perron P (1988) Testing for a unit root in time series regression. Biometrika 75(2):335–346
Rath BN, Hermawan D (2019) Do information and communication technologies foster economic growth in Indonesia? Buletin Ekonomi Moneter dan Perbankan 22(1):103–122
Rehman A, Ma H, Chishti MZ, Ozturk I, Irfan M, Ahmad M (2021) Asymmetric investigation to track the effect of urbanization, energy utilization, fossil fuel energy and CO2 emission on economic efficiency in China: another outlook. Environ Sci Pollut Res 28(14): 17319–17330
Sahoo D, Mathiyazhagan MK (2003) Economic growth in India: "Does Foreign Direct Investment inflow matter?". The Singapore Economic Review 48(02):151–171
Samir S, Mefteh H (2020) Empirical analysis of the dynamic relationships between transport, ICT and FDI in 63 countries. Int Econ J 1: 24. https://doi.org/10.1080/10168737.2020.1765186
Shaari MS, Hussain NE, Abdullah H, Kamil S (2014) Relationship among foreign direct investment, economic growth and CO2 emission: a panel data analysis. Int J Energy Econ Policy 4(4):706
Sinha M, Sengupta PP (2019) FDI inflow, ICT expansion and economic growth: an empirical study on Asia-pacific developing countries. Glob Bus Rev 0972150919873839
Sokhanvar A (2019) Does foreign direct investment accelerate tourism and economic growth within Europe? Tour Manag Perspect 29:86–96
Soper DS, Demirkan H, Goul M, St Louis R (2012) An empirical examination of the impact of ICT investments on future levels of institutionalized democracy and foreign direct investment in emerging societies. J Assoc Inf Syst 13(3):3
Sothan S (2017) Causality between foreign direct investment and economic growth for Cambodia. Cogent Economics & Finance 5(1): 1277860
Stanley TD, Doucouliagos H, Steel P (2018) Does ICT generate economic growth? A meta-regression analysis. J Econ Surv 32(3):705–726
Szkorupová Z (2014) A causal relationship between foreign direct investment, economic growth and export for Slovakia. Procedia economics and finance 15:123–128
Tahir M, Estrada MAR, Afridi MA (2019) Foreign inflows and economic growth: an empirical study of the SAARC region. Econ Syst 43(3-4):100702
Tee E, Larbi F, Johnson R (2017) The effect of foreign direct investment (FDI) on the Ghanaian economic growth. Journal of Business and Economic Development 2(5):240–246
Temiz D, Gökmen A (2014a) FDI inflow as an international business operation by MNCs and economic growth: an empirical study on Turkey. Int Bus Rev 23(1):145–154
Temiz D, Gökmen A (2014b) FDI inflow as an international business operation by MNCs and economic growth: an empirical study on Turkey. Int Bus Rev 23(1):145–154
Williams K (2017) Foreign direct investment, economic growth, and political instability. J Econ Dev 42(2):17–37
World Bank (2017) Information and communication technologies. Retrieved July 12, 2020 from http://www.worldbank.org/en/topic/ict/overview
Xing Z (2018) The impacts of information and communications technology (ICT) and E-commerce on bilateral trade flows. IEEP 15(3): 565–586
Yakunina RP, Bychkov GA (2015) Correlation analysis of the components of the human development index across countries. Procedia Economics and Finance 24:766–771
Zhang J (2019) The dynamic linkage between information and communication technology, human development index, and economic growth: evidence from Asian economies. Environ Sci Pollut Res 26(26):26982–26990