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ICT Leapfrogging Amidst Labour Force-Economic Growth Nexus in EAP and ECA Regions

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Abstract: Towards achieving the 2030 United Nations Sustainable Development Goals, this study revisits the information and communication technology (ICT) leapfrogging hypothesis of Steinmueller (2001), and Fong (2009) to expand the literature by testing its relevance in the labour force-growth dynamics in Asia. To achieve this, the study addresses four objectives: (i) test the ICT leapfrogging hypothesis; (ii) investigate the growth-enhancing impact of labour; (iii) examine whether ICT enhances or distorts the productivity of labour on economic growth; and (iv) if these effects differ by economic development. The study uses an unbalanced panel data on 81 countries located in East Asia and Pacific (EAP) and Europe and Central Asia (ECA) from 2010 to 2019. Two estimation techniques, namely panel spatial correlation consistent fixed effects (PSCC-FE) and random effects instrumental variables two-stage least squares (RE-IV2SLS), are deployed. To appraise if the impact differs by economic development, the study engages income group analysis. Among other findings: the leapfrogging hypothesis holds; labour is a significant predictor of economic growth; mobile phones usage is a more potent ICT indicator with more leapfrogging potentials relative to fixed telephones subscription; the net effect of labour on growth is mostly positive in the mobile phones' models.

Keywords: economic growth; labour force; leapfrogging; ICT usage; moderation; EAP; ECA.

JEL classification: G20; I21.

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1. INTRODUCTION

The information and communication technology (ICT) "leapfrogging" hypothesis has been represented and explained in diverse ways. According to Steinmueller (2001), ICT "leapfrog" is interpreted to mean when developing economies use ICT to bypass key developmental stages to narrow the productivity gaps between developed and developing economies. In other words, these economies use ICT to jump-start their development goals. A slight deviated interpretation is provided by Fong (2009) who defined ICT "leapfrog" as a situation where ICT being an advanced and state-of-the-art technology is applied to an area previously not deployed to achieve some spontaneous development. Given these submissions, this study aligns with both arguments as they aid in actualising the main objective of this paper which is to test if ICT usage influences the labour-growth dynamics. The leapfrog potentials of ICT permeate all paths of the 2030 United Nations Sustainable Development Goals (SDG)[1].

It is established that ICT can enhance financial inclusion by enabling mobile banking services (Asongu & Tchamyou, 2015; Ofori *et al.*, 2022). This can reduce poverty and inequality (SDG 1 and 10). Through the dissemination of information on agricultural yield, soil composition, and weather forecasts ICT contributes to the reduction of hunger and aids in sustaining food security (Issahaku *et al.*, 2018; Ejemeyovwi *et al.*, 2021) satisfying SDG 2 and 12 in addition to enhancing the wellbeing of the population (SDG 3). ICT drives inclusive education via connectivity such that learning resources and opportunities are available to those initially excluded (SDG 4). It also empowers women and girls through ICT-powered education and online trainings (SDG 5) (George *et al.*, 2021a; George *et al.*, 2021b; Adeleye *et al.*, 2022a). Among others, ICT provides the tools and applications required to manage water and sanitation (SDG 6); helps organisation monitor energy usage (SDG 7) which curbs carbon emissions, reduce environmental degradation ensuring a green environment (SGG 11) and protecting the ecosystem (SDG 13, 14, and 15). ICT innovation and usage connects SDG 8 (providing decent work and economic growth) and SDG 9 (innovation an infrastructure) via improving employment opportunities and the productivity of labour (Grigoli *et al.*, 2020; Ngoa & Song, 2021; Olurinola *et al.*, 2021); drives inclusive industrialisation, globalisation and economic growth (Adeleye & Eboagu, 2019; Adeleye *et al.*, 2021a; Adeleye *et al.*, 2021b; Anser *et al.*, 2021) to satisfy SDG 17. Lastly, ICT adoption strengthens institutions by improving the quality of governance via sharing information to the general public (Zuiderwijk & Janssen, 2014; Sassi & Ali, 2017) satisfying SDG 16.

Also, labour is essential to the production and marketing value chain and several studies have shown that it is a significant contributor to economic growth (Tsani *et al.*, 2013; Liu, 2014; Docquier *et al.*, 2019; Cylus & Al Tayara, 2021; Hou *et al.*, 2021; F. Zhang *et al.*, 2021; X. Zhang & Wang, 2021). Labour is needed in all spheres of the economy as the labour force participation[2] rate measures the active workforce of an economy calculated by the sum of all workers that are employed or actively seeking employment divided by the number of the working-age population. Some studies have also connected the ICT-labour nexus to show that ICT enables the performance of labour (Ceccobelli *et al.*, 2012; Herman, 2020; Kim *et al.*, 2021; F. Zhang *et al.*, 2021).

However, this paper deviates to explore if ICT moderates the impact of labour on economic growth in Asia. In other words, does ICT influence the labour-growth dynamics in Asia? This, to the best of our knowledge, is a gap in the labour-growth literature. Following Hayes (2015), the moderating role of ICT on the labour-growth nexus is graphically illustrated

in Figure no. 1. To satisfy the four study objectives: (i) Path A tests the Steinmueller (2001), Fong (2009), Sein *et al.* (2019) and Avgerou (2017) ICT leapfrogging hypothesis; (ii) Path B probes the growth-enhancing impact of labour force; (iii) Path C evaluates if ICT enhances or distorts the productivity of labour on economic growth; and (iv) examines if paths A-C is heterogeneous by income groups.

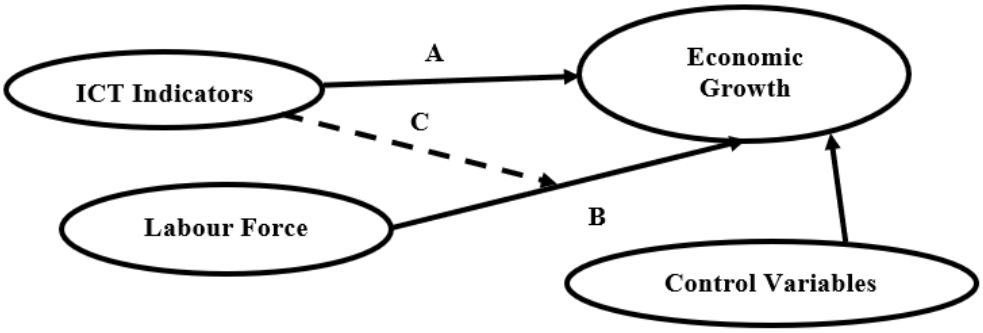

Figure no. 1 – Schema on the ICT-Labour-Economic Growth Dynamics

To probe the discourse, data on 81 countries[3] located in East Asia and Pacific (EAP) and Europe and Central Asia (ECA) from 2010 to 2019 is used. The main variables of interest are per capita GDP (proxy for economic growth); mobile phones and fixed telephone subscriptions as indicators of ICT and total labour force participation rate. ICT is a general term that captures any communication device or application encompassing cellular phones, fixed wireless, broadband, computers, network hardware and software, satellite systems etc. (Fong, 2009; Adeleye & Eboagu, 2019). This current study restricts to using mobile subscriptions (given its ease of carriage and portability the mobile phone is used by everyone), fixed telephone subscriptions (common with corporate establishments) as ICT indicators. For the most part, the results from our study align with previous studies. Outcomes reveal that ICT exerts a nonlinear U-shaped relationship with economic growth satisfying that the leapfrogging hypothesis holds, labour significantly predicts economic growth; the net effect of labour is consistently positive in mobile phones models; mobile phone is a more potent ICT indicator to jumpstart economic progress and lastly, the results from the income groups are heterogeneous. The rest of the study is organised as follows: Section 2 reviews the literature; Section 3 outlines the data and model; Section 4 discusses the results while Section 5 concludes with policy recommendations.

2. BRIEF EMPIRICAL REVIEW

This section reviews the extant literature on the link between ICT and economic growth by expounding on the leapfrogging hypothesis of Steinmueller (2001), Avgerou (2017) and Sein *et al.* (2019); further to this we draw empirical findings on the labour force-economic growth nexus from Jarmołowicz and Knapińska (2011) labour market theories; lastly we find empirical validations to situate the interaction of ICT and labour force. Table no. 1 summarizes the reviewed literature on ICT and economic growth (1-15), labour force and economic growth (16-25), and ICT and labour force (26-40).

Table no. 1 – Summary of Reviewed Literature on ICT, Labour Force and Economic Growth

S/N	Author(s)	Scope	Technique	Outcome
1	Adeleye *et al.* (2021a)	53 African countries, 2005-2015	BLSDV, DGMM	ICT ↑ EG and IG
2	Appiah-Otoo and Song (2021)	122 countries, 2002-2017	IV-GMM	ICT ↑ EG in both rich and poor countries but ICT revolution ↑ EG in poor countries.
3	Arvin et al. (2021)	G20 countries, 1961-2019	PGCM	ICT ↑ EG
4	Hussain et al. (2021)	South Asia, 1995-2016	FMOLS, Panel VECM	ICT ↑ EG
5	Kallal et al. (2021)	Tunisia, 1997-2015	PMG-ARDL	ICT ↑ EG
6	Kim et al. (2021)	22 countries, 2011-2016	POLS, FE	Mobile ICT ↑ NP in DCs; no impact of wired ICT for either DCs or LDCs.
7	Ofori and Asongu (2021)	SSA, 1980-2019	SGMM	ICT ↑ IG
8	Usman et al. (2021)	South Asia, 1990-2018	BT, ECM	ICT ↑ EG in India only
9	Ejemeyovwi and Osabuohien (2020)	WA, 2004-2014	SGMM	ICT has no effect on IG
10	Jung and Lopéz-Bazo (2020)	27 Brazilian states, 2007-2011	OLS, IV-FE	ICT ↑ EG
11	Myovella et al. (2020)	41 SSA, 33 OECD countries, 2006-2016	OLS, FE, GMM	ICT ↑ EG
12	Nguyen et al. (2020)	13 G-20 countries, 2000-2014	FMOLS, QR	ICT ↑ EG
13	Adeleye and Eboagu (2019)	54 African countries, 2005-2015	POLS, SGMM	ICT ↑ EG
14	Donou-Adonsou (2019)	45 SSA countries, 1993-2015	FE, GMM	ICT ↑ EG
15	Sepehrdoust and Ghorbanseresht (2018)	OPEC, 2002-2015	GMM	ICT ↑ EG
16	Acheampong et al. (2021)	23 EE, 1970-2015	IV-GMM	LF ↓ EG
17	Adeleye *et al.* (2021b)	15 industrialised countries, 1976-2018	FE, RE	LF ↑ Output
18	Anyanwu et al. (2021)	Nigeria, 1981-2015	OLS	Female LF ↓ EG
19	Ogundipe et al. (2021)	Nigeria, 1981-2018	JCT	LF ↑ EG
20	Olarewaju et al. (2021)	Manufacturing firms in Nigeria	MDS	LF ↑ Output
21	Yıldırım and Akinci (2021)	MIC, 2001-2016	POLS, FE, DGMM, SGMM	U-shape nexus between female LF and EG
22	X. Zhang and Wang (2021)	China, 1985-2014	FE	LF growth rate ↓ EG
23	Appiah et al. (2020)	15 ECOWAS countries, 1996-2017	SGMM	LF ↯ EG
24	Rahman et al. (2020)	5 South Asian countries, 1990-2017	PGCM, FMOLS, DOLS, GMM	LF ↑ EG
25	Ruiters and Charteris (2020)	South Africa, 2008-2018 (quarterly)	ARDL	Female LFP ↯ EG
26	Ejemeyovwi *et al.* (2021)	7634 households, Nigeria, LSMIS,	Logit	ICT ↑ food security of farming households.
27	Ngoa and Song (2021)	48 African countries, 2001-2017	FE, SGMM	ICT ↑ female LFP

S/N	Author(s)	Scope	Technique	Outcome
28	Shahnazi (2021)	28 EU countries, 2007-2017	SDM	ICT spill-overs ↑ LFProd.
29	F. Zhang et al. (2021)	China, 2004-2006	FE	Enterprise ICT ↓ LF income and demand.
30	Grigoli et al. (2020)	24 European economies, 2000-2016	Driscoll and Kraay (1998) PSCC	Automation ↓ LFP
31	Herman (2020)	Romania, 2008-2018	DS	Low digital economy ↓ LFP
32	Koutroumpis et al. (2020)	9,474 European firms, 2004-2013	GMM	R&D ICT ↑ TFP
33	Gal et al. (2019)	20 OECD countries plus Turkey, 2010-2015	ECM	ICT ↑ TFP
34	Chung (2018)	Korea, 1996-2015	DGEM	ICT ↑ growth
35	Pieri et al. (2018)	OECD industries, 1973-2007	SFM	ICT ↓ PI
36	Edquist and Henrekson (2017)	50 Swedish industries; 1993-2013	OLS	ICT ↯ TFP
37	Liao et al. (2016)	24 USA ICT-using industries, 1977–2005	MCMC	ICT ↑ TFP
38	Luo and Bu (2016)	6,236 from 27 EE, 2007	HLM	ICT ↑ productivity
39	Mitra et al. (2016)	India, 1994-2010	FMOLS, PC, DPDM	ICT ↑ TFP
40	Strobel (2016)	Germany and the USA	OLS	ICT ↑ TFP

Note: ↑: Increases/improves/stimulates; ↓: Reduces/reduction/declines; ↯: No effect; ARDL: Autoregressive distributed lag model; BLSDV: Bootstrapped least squares dummy variables; BT: Bounds testing; CGEM: Computable General Equilibrium Modeling; DCs: Developing countries; DGEM: Dynamic general equilibrium model; DGMM; Difference generalised method of moments; DOLS: Dynamic ordinary least squares; DPDM: Dynamic panel data model; DS: Descriptive statistics; ECM: Error correction model; ECOWAS: Economic Community of West African States; EE: Emerging Economies; EG: Economic growth; EU: European Union; FE; Fixed effects; FMOLS: Fully modified ordinary least squares; GM: Gravity model; HLM; Hierarchical linear modeling; ICT: Information and communication technology; IG: Inclusive growth; IV-GMM: Instrumental variables-generalised method of moments; JCT: Johansen cointegration technique; LDCs: Less developed countries; LFP: labour force participation; LFProd: Labour force productivity; LSMIS: Living Standard Measurement Integrated Survey; MCMC; Markov Chain Monte Carlo; MDS: Micro-Data Survey; MIC: Middle-Income countries; NP: national productivity; OECD: Organisation for Economic Cooperation and Development; OPEC: Organisation of Petroleum Exporting Countries; PC: Panel cointegration; PGCM: Panel-Granger causality model; PI: Production inefficiency; PMG: Pooled mean group; POLS: Pooled ordinary least squares; PSCC: Panel-spatial correlation consistent; QR: Quantile regression; R&D: Research and Development; RE: Random effects; SGMM: System generalised method of moments; SDM: Spatial Durbin Model; SFM: Stochastic Frontier Model; SSA: Sub-Saharan Africa; VECM: Vector error correction model; WA: West Africa

Source: authors' compilation

Our study differs from those highlighted in Table no. 1 with the introduction of moderation modelling technique as none of these studies used this approach to investigate the relationship between economic growth and labour force. Hence, we contribute to the body of knowledge by examining the moderation effect of ICT on the labour-growth nexus. We further engage robust analyses with aggregated and dis-aggregated samples to probe the discourse.

3. DATA AND MODEL

3.1 Variables, Justification and Expectations

To probe the discourse, an unbalanced panel data of eight variables on 81 countries located in East Asia and Pacific (EAP) and Europe and Central Asia (ECA) from 2010 to 2019 is used. The peculiarity of these regions, their cosmopolitan nature and diverse income structure are the motives for choosing both regions the scope. For instance, (1) both EAP and ECA have semblance of Asian countries; (2) Oceanic countries can be separated from the EAP region; (3) some parts of Europe are in the ECA region; and (4) both regions have diverse income groups. To allow for more countries, we expanded the scope such that only those without sufficient observations on the variables of interest are excluded from the sample. All the variables are obtained from World Bank (2020) – World Development Indicators (WDI). The dependent variable is per capita GDP (PC) which is the proxy for economic growth; the main independent variables are ICT indicators - mobile cellular subscription (MOB), and fixed telephone subscription (FTEL), and labour force participation (LF). There are four control variables: individuals using the Internet (NET), education index (EDUC), institutional quality index (IQI), and gross fixed capital formation (GFCF). Lastly, two interaction terms: the square of ICT is included to test the leapfrogging hypothesis and LAB*ICT is incorporated to test if ICT improves or distorts the impact of labour force participation on economic growth.

On a *priori* expectations, ICT has a positive relationship with economic growth (Sein *et al.*, 2019; Adeleye *et al.*, 2021a; Olurinola *et al.*, 2021; Haldar *et al.*, 2022; Adeleye, 2023). Coupled with that, the leapfrogging hypothesis states that ICT is the platform upon which developing economies can skip developmental stages (Steinmueller, 2001; Sein & Harindranath, 2004; Avgerou, 2017; Adeleye *et al.*, 2022a; Adeleye *et al.*, 2022b). Labour is an critical element for growth (Shahid, 2014; Olarewaju *et al.*, 2021; X. Zhang & Wang, 2021), Internet usage contributes to economic productivity (Visser, 2019; Shahnazi, 2021), education which is human capital exerts a positive impact on growth (Čadil *et al.*, 2014; Pelinescu, 2015), quality institutions provide the enabling environment for growth to thrive (Acemoglu & Robinson, 2010; Bahamonde & Trasberg, 2021), and lastly capital is a vital growth input (Lach, 2010; Ahmed *et al.*, 2016; Adeleye *et al.*, 2021b). The variables description, sources and a priori expectations are shown in Table no. 2.

Table no. 2 – Variables, Description and Signs

Variable	Description	Signs
PC	GDP per capita (constant 2010 US$)	N/A
LAB	Labor force participation rate, total (% of total population ages 15-64) (modeled ILO estimate)	+
MOB	Mobile cellular subscriptions (per 100 people)	+
FTEL	Fixed telephone subscriptions (per 100 people)	+
NET	Individuals using the Internet (% of population)	+
EDUC	Education Index	+
IQI	Institutional Quality Index	+
GFCF	Gross capital formation (% of GDP)	+

Source: authors' compilations

3.2 Theoretical Framework and Empirical Model

To address the increasing impact of ICT innovation on economic growth, our study draws from the leapfrogging hypothesis that ICT innovation is the platform upon which developing economies skip developmental stages (Steinmueller, 2001; Niebel, 2018). Linked to that is the ICT4D theoretical frameworks of Sein *et al.* (2019) and Avgerou (2017) which posit that ICT innovation drives rapid output growth and labour productivity across countries. Several studies have shown that ICT investments exert positive impact on the economy (Adeleye & Eboagu, 2019; Ejemeyovwi & Osabuohien, 2020; Adeleye *et al*., 2021a; Kim *et al.*, 2021). Secondly, from the theory of economic growth (Jones, 1975), output is a direct function of capital, labour and technology which provides sufficient justification for the interaction of labour and ICT in order to evaluate the overall impact of labour on growth. To this end, this study conjectures that (1) ICT will exert an increasing monotonic effect on growth, and (2) ICT may improve the overall impact of labour force on economic growth such that productivity improves with more ICT innovation and adoption. Hence, to address these suppositions the empirical approach of Adeleye *et al.* (2021a) is modified into three distinct models.

To test the leapfrogging hypothesis (Path A of Figure no. 1), the first objective specifies economic growth as an increasing function of ICT (given the inclusion of the square of ICT) and a set of control variables:

$$\ln PC_{it} = \varphi_0 + \varphi_1 \boldsymbol{ICT'}_{it} + \varphi_2 \boldsymbol{ICT'^2}_{it} + \phi \boldsymbol{K'}_{it} + \mu_i + \gamma_t + v_{it} \quad (1)$$

Holding ICT and other control variables constant, the second objective introduces labour force into Equation (1) to observe its impact on growth (Path B of Figure no. 1):

$$\ln PC_{it} = \eta_0 + \eta_1 \boldsymbol{ICT'}_{it} + \eta_2 \boldsymbol{ICT'^2}_{it} + \eta_3 \ln LAB_{it} + \omega \boldsymbol{R'}_{it} + \mu_i + \delta_t + \tau_{it} \quad (2)$$

To achieve the third objective, Equation (2) is augmented to accommodate the interaction of labour force and each ICT to examine the interaction effects on economic growth (Path C of Figure no. 1):

$$\ln PC_{it} = \psi_0 + \psi_1 \ln \boldsymbol{ICT'}_{it} + \psi_2 \ln LAB_{it} + \psi_3 (\ln LAB_{it} * \ln \boldsymbol{ICT'})_{it} + \alpha \boldsymbol{W'}_{it} + \mu_i + \rho_t + s_{ii} \quad (3)$$

where, ln = natural logarithm; PC_{it} = real per capita GDP (proxy for economic growth); $\boldsymbol{ICT'}_{it}$ = vector of ICT indicators (MOB, FTEL); LAB_{it} = labour force; $\varphi_i, \eta_i, \psi_i$ = parameters to be estimated; $\phi \boldsymbol{K'}_{it}$, $\omega \boldsymbol{R'}_{it}$, $\alpha \boldsymbol{W'}_{it}$ = vector of control variables (NET, EDUC, GFCF, and IQI) and their corresponding parameters; μ_i = individual fixed effects; $\gamma_t, \delta_t, \rho_t$ = year dummies; and $v_{it}, \tau_{it}, s_{it}$ = general error terms. Equations (1) to (3) are further modified for income groups analysis to satisfy the fourth objective.

From Equation (1), (i) $\varphi_1 < 0$, $\varphi_2 > 0$ reveals a U-shaped relationship and affirms that the leapfrogging hypothesis holds; (ii) $\varphi_1 > 0$, $\varphi_2 < 0$ shows an inverse U-shaped relationship; (iii) $\varphi_1 > 0$, $\varphi_2 > 0$ illustrates a monotonically increasing linear relationship; (vi) $\varphi_1 < 0$, $\varphi_2 < 0$ depicts a monotonically decreasing linear relationship; and (vii) $\varphi_1 = 0$, $\varphi_2 = 0$ indicates no relationship.

Note, from Equation (3) the expectation is that $\psi_1 > 0$ and $\psi_2 > 0$ and the sign of the coefficient of the interaction term, ψ_3, gauges if the interaction of ICT innovation with labour boosts or alters the impact of labour force on economic growth. A positive (negative) ψ_3 shows that ICT improves (distorts) the performance of labour force on growth. However, the net effect of labour force on economic is evaluated at values of ICT innovation and the formula is given as:

$$\frac{\partial \ln PC}{\partial \ln LAB} = \psi_2 + \psi_3 \ln \boldsymbol{ICT}' \quad (4)$$

So, if $\psi_3 > 0$ it implies that ICT usage enables labour performance on economic growth. However, if $\alpha_3 < 0$, the overall impact of labour force on growth depends on the magnitude of the negative. If the negative sign of ψ_3 outweighs the positive sign of ψ_2 then ICT usage distorts the impact of labour force on growth. On the contrary, if the negative sign of ψ_3 is less than the positive sign of ψ_1 it suggests that the distortionary effect of ICT is not sufficient to constrain the positive effect of labour force on economic growth. Finally, if $\psi_3 = 0$ implies the interaction of ICT usage with labour force has no significant impact on growth.

3.3 Estimation Techniques

The estimation techniques are panel spatial correlation consistent fixed effects estimator (PSCC-FE) and the random effects instrumental variables two-stage least squares (RE-IV2SLS). To control for cross-sectional dependence and possible endogeneity, Equations (1) to (3) are estimated with the Driscoll and Kraay (1998) panel spatial correlation consistent (PSCC) standard errors fixed effects (FE-within) regression technique. The procedure corrects the standard errors of the coefficient estimates for possible dependence (Cameron & Trivedi, 2005; Hoechle, 2007). Finally, in the event of possible endogeneity and on the assumption that the regressors are orthogonal to the error terms, the two-stage least-squares random-effects estimator (RE-IV2SLS) which uses the Baltagi EC2SLS random-effects estimator (Baltagi, 2013) is deployed.

4. RESULTS AND DISCUSSIONS

4.1 Summary Statistics

Table no. 3 shows the historical properties among the variables. With emphasis on GDP/capita, mobile phones subscriptions, fixed telephone subscriptions, and labour force participation rate, the average GDP/capita in the data is US$21,899.94 with a standard deviation of 23209.84 indicating that countries in the sample are widely dispersed from the mean. Luxembourg (ECA, high income) has the highest GDP/capita of US$111,043.50 in 2019. The country consistently tops the highest per capita income from 2010 to 2019 while Cambodia (EAP, lower-middle income) has the lowest at US$785.50 in 2010. On the ICT indicators, the average mobile phones users per 100 people is 45,253,575 and China (EAP, upper-middle income) consistently has the highest number of persons from 2010 to 2019 while the country with the lowest mobile phone users is Tuvalu (EAP, upper-middle

income) with 1,600 in 2010. The average number of fixed telephone subscriptions is 9,069,212 with China (EAP, upper-middle income) consistently has the highest number of persons from 2010 to 2019 while the country with the lowest fixed telephone users is Nauru (EAP, upper-middle income) with zero values from 2010 to 2019. Lastly, the average labour force participation rate is 70.271 and the country with the highest labour force participation is Iceland (ECA, high income) with 89.09 while the lowest is Moldova (ECA, lower-middle income) with 43.72.

Table no. 3 – Summary Statistics

Variable	*Full Sample*			*High Income*		
	Obs	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
PC	796	21899.944	23209.839	388	39954.334	21421.275
MOB	760	45253575	1.57E+08	382	22949493	34438905
FTEL	768	9069212	29269308	387	8388941.6	14544185
GFCF	705	23.62	6.486	371	21.687	4.538
LAB	740	70.271	8.557	380	73.52	5.457
NET	720	60.713	26.438	366	79.632	11.88
EDUC	733	0.761	0.129	360	0.855	0.055
IQI	784	0.049	2.178	374	1.984	1.195
Variable	***Lower-Middle Income***			***Upper-Middle Income***		
	Obs	**Mean**	**Std. Dev.**	**Obs**	**Mean**	**Std. Dev.**
PC	180	2333.212	1082.029	228	6623.226	2873.096
MOB	168	42476325	81647796	210	88047562	2.82E+08
FTEL	168	2984897.4	6527967.8	213	15104092	51126873
GFCF	150	27.109	7.724	184	24.675	7.276
LAB	160	68.878	10.917	200	65.212	8.515
NET	150	27.912	20.117	204	50.89	19.686
EDUC	170	0.603	0.127	203	0.728	0.062
IQI	180	-2.089	1.057	230	-1.424	1.066

Note: PC = GDP per capita; MOB = Mobile cellular subscription; FTEL = Fixed telephone subscription; GFCF = gross fixed capital formation; LAB = Labour force participation; NET = Individuals using the Internet; EDUC = Education index; IQI = Institutional quality index; 1.57E+08 = 157,000,000.00.

Source: authors' computations

4.2 Pairwise Correlation Analysis

From the pairwise correlation presented in Table no. 4, all the independent variables apart from gross fixed capital formation have positive and statistically significant association with GDP/capita. Though the correlation coefficient for EDUC/NET is 0.814 and that of IQI/EDUC is 0.784, their respective variance inflation factors (VIF) are 2.02, 2.03 and 2.04 which are below the benchmark of 10 from which multicollinearity becomes a concern (see Annex Table 1B).

Table no. 4 – Pairwise Correlation Analysis

Variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
(1) lnPC	1.000							
(2) lnMOB	0.152***	1.000						
(3) lnFTEL	0.365***	0.916***	1.000					
(4) lnGFCF	-0.312***	0.054	-0.095**	1.000				
(5) lnLAB	0.368***	0.237***	0.225***	-0.062	1.000			
(6) lnNET	0.736***	0.253***	0.423***	-0.325***	0.260***	1.000		
(7) EDUC	0.811***	0.139***	0.388***	-0.347***	0.275***	0.814***	1.000	
(8) IQI	0.876***	0.006	0.183***	-0.284***	0.380***	0.642***	0.748***	1.000

Note: *** p<0.01, ** p<0.05, * p<0.1; ln = Natural logarithm; PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

4.3 Full Sample Results

There is evidence of the leapfrogging hypothesis from the results displayed in Table no. 5. Holding the control variables constant, columns [1] and [4] reveal that mobile phones and fixed telephones usage show a statistically significant U-shaped relationship with economic growth. It is inferred that at the initial stage of ICT innovation due to the learning curve and adoption, economic growth slows down (negative level term) but as people become skilled in the application of ICT apparatus for productive economic activities intensifying its usage, economic growth speeds up (positive squared term). Specifically, these findings align with Ghosh (2016), Kumar *et al.* (2016), Haftu (2019) and Myovella *et al.* (2020) who establish that mobile telephony and fixed telephone usage have contributory impact on economic growth. Overall, this outcome supports the Steinmueller (2001), Sein *et al.* (2019) Sein et al. (2018) and Avgerou (2017) leapfrogging conjectures that ICT can be used to jumpstart economic growth as well as related studies that find ICT as a positive and significant predictor of growth (Adeleye & Eboagu, 2019; Visser, 2019; Appiah *et al.*, 2020; Asongu & Odhiambo, 2020; Adeleye *et al.*, 2021a; Adeleye *et al.*, 2021b; Appiah-Otoo & Song, 2021; Kim *et al.*, 2021). This outcome satisfies our first objective.

From columns [2] and [5], the results indicate that labour force is a statistically significant positive predictor of economic growth at the 1% level. it indicates that the elasticity of contribution of labour to growth is between 0.55 and 0.67 percent, on average, ceteris paribus. This conforms with previous positive labour-growth relation established by Yıldırım and Akinci (2021), Ngoa and Song (2021), Ruiters and Charteris (2020), Grigoli *et al.* (2020), and Adeleye and Eboagu (2019). These results confirm that labour work is an essential input in the production process such that an active workforce will exert a positive impact on output. Also, the positive impact of labour is evident despite controlling for the nonlinearity of ICT amongst other covariates. With this outcome, the second objective is achieved.

Table no. 5 – Full Sample Results

Variables	PSCC-Fixed Effects, Main						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-0.320***	-0.941***	0.408***	-0.00512	-0.0111	0.576*	-0.0230	-0.394*	2.404**	0.00398	0.0852**	8.730***
	(-4.767)	(-10.32)	(3.937)	(-0.710)	(-0.880)	(1.747)	(-0.211)	(-1.875)	(2.227)	(0.175)	(2.093)	(6.564)
lnICTSQ	0.00956***	0.0288***		0.00455**	0.00380		7.69e-05	0.0117*		0.00737	-0.0219**	
	(4.782)	(10.20)		(2.372)	(1.431)		(0.0222)	(1.802)		(1.298)	(-2.248)	
lnNET	0.0687***	0.0963***	0.0771***	0.0532***	0.0626***	0.0660***	0.0704***	0.0923***	0.0790***	0.0688***	0.173***	0.0939***
	(9.845)	(12.83)	(12.35)	(7.357)	(8.201)	(9.428)	(4.865)	(6.402)	(5.200)	(4.757)	(6.853)	(5.571)
lnGFCF	0.100***	0.0802***	0.0747***	0.0743***	0.0725***	0.0731***	0.0756***	0.0613***	0.0407	0.109***	0.0765**	0.0863***
	(10.73)	(5.922)	(5.609)	(5.808)	(5.345)	(5.398)	(3.154)	(2.616)	(1.527)	(4.194)	(2.340)	(2.650)
EDUC	0.424***	0.422***	0.673***	0.610***	0.632***	0.678***	1.752***	1.640***	1.956***	2.571***	3.070***	2.880***
	(5.419)	(8.407)	(6.435)	(6.816)	(6.888)	(6.821)	(7.473)	(7.265)	(8.115)	(8.296)	(8.323)	(8.423)
IQI	0.0561***	0.0638***	0.0636***	0.0522***	0.0628***	0.0633***	0.0924***	0.0991***	0.0981***	0.0881***	0.128***	0.126***
	(3.826)	(4.145)	(4.057)	(3.494)	(3.981)	(3.992)	(8.330)	(9.257)	(8.436)	(7.806)	(8.338)	(8.376)
lnLAB		0.672***	2.157***		0.550***	0.944***		0.877***	9.900**		3.534***	7.720***
		(4.533)	(5.998)		(3.919)	(2.847)		(6.290)	(2.439)		(7.316)	(7.256)
lnLAB*lnICT			-0.101***			-0.132*			-0.571**			-2.010***
			(-4.278)			(-1.728)			(-2.249)			(-6.550)
Net Impact			**0.58%**			**-0.89%**			**0.98%**			**-20.20%**
Constant	11.08***	13.17***	-0.468	8.413***	6.080***	4.312***	7.910***	7.154***	-34.22**	6.741***	-9.068***	-26.82***
	(19.61)	(28.10)	(-0.291)	(147.0)	(10.67)	(3.052)	(8.649)	(3.830)	(-1.982)	(22.92)	(-3.917)	(-5.642)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	635	626	626	633	625	625	565	558	558	563	556	556
Countries	70	68	68	69	68	68	69	68	68	69	68	68
F/Wald Statistic	196747	248438	234307	43256	101044	93518	903.3	1026	934.5	881.2	573.6	600.0

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation; VIF = Variance inflation factor.

Source: authors' computations

Next, the results in columns [3] and [6] computes the net impact of labour force on economic growth conditioned on average values of ICT[4]. In essence, these outcomes show if ICT enhances or distorts the impact of labour on economic growth. At face value, the interaction effect on economic growth is negative statistically significant across all model specification but further examination reveals that labour force has a positive (negative) net effect on growth for mobile phones (fixed telephones). Following from Equation (4) the net effect is computed as:

[2.157+(-0.101*15.615)] = 0.58% for mobile phones; and
[0.944+(-0.132*13.891)] = -0.89% for fixed telephone, respectively.

Deductively, it suggests that labour force contributes positively to growth when mobile phone adoption is accounted relative to the negative outcome observed with fixed telephone usage. These outcomes are not only plausible but lend credence to the following conclusions: (1) an individual may be more productive using a mobile phone than a fixed telephone; (2) mobile phones usage has more advantages than a fixed telephone such as easy-to-carry around, affordability and reduced time/costs enabling sellers to advertise and connect to many consumers at the same time (Adeleye & Eboagu, 2019; Adeleye *et al.*, 2021a); and (3) mobile phones usage is most common among individuals unlike fixed telephone that is common with corporate organisations. The net outcomes of labour on growth after accounting for mobile phones and fixed telephones show that ICT is an important growth factor (Kim *et al.*, 2021; Ngoa & Song, 2021). This is another angle to the contributory role of ICT on economic growth and addresses our third objective.

Robustness is tested using the random effects IV-2SLS technique which accounts for any possible endogeneity in the model. The results shown in columns [7] to [12] are not significantly different from the main analysis. In columns [7] and [10] the effect of ICT on growth is inconclusive due to statistically insignificant coefficients. Columns [8] and [11] reveal that the growth-inducing impact of labour force is sustained and lastly the interaction effect, though negative, shows that the net impact of labour conditioned on average value of mobile phone (fixed telephone) is 0.98% (-20.20%). Again, it is observed that labour's productivity is enhanced when mobile phone usage is intensified relative to fixed telephones. This gives some validation to the results obtained from the main analysis.

4.4 Income Groups Results

The results of the income groups are displayed in Table no. 6 (High Income), Table no. 7 (Lower-middle Income) and Table no. 8 (Upper-middle Income) and their interpretations are taken in turns. Like Table no. 5, interpretation is restricted to the variables of interest. From Table no. 6, the nonlinear U-shaped relationship between ICT and growth is evident mostly for the mobile phone models. The output elasticity is higher from mobile phone usage which gives the indication that it is a more potent ICT indicator relative to fixed telephone which may jumpstart growth in developed economies. These results situate previous studies who find that ICT increases output in developed high income economies (Ceccobelli *et al.*, 2012; Mačiulytė-Šniukienė & Gaile-Sarkane, 2014; Niebel, 2018; Appiah-Otoo & Song, 2021). As expected, the effect of labour force on growth is positive and statistically significant in seven out of eight models suggesting that labour force enhances output in developed economies (Docquier *et al.*, 2019; Ruiters & Charteris, 2020). The interaction coefficient is

negative and statistically significant only in column [3] while it is zero[5] in the rest models. Hence, the net impact of labour force on growth when ICT[6] is accounted for at the mean value is computed as 1.72%, 2.12%, and 1.94% for mobile phones and fixed telephones, respectively. These outcomes support the labour-enhancing effect of ICT (Ceccobelli *et al.*, 2012; Grigoli *et al.*, 2020; Ngoa & Song, 2021).

For the results of lower-middle income countries shown in Table no. 7, ICT reveals a significant U-shaped relation to economic growth in six out of eight models. Again, it is inferred that the leapfrog hypothesis holds in developing economies (Steinmueller, 2001; Sein & Harindranath, 2004; Adeleye & Eboagu, 2019; Sein *et al.*, 2019). The impact of labour force is positive and statistically significant in three models mostly for the main analysis. Thus, we find evidence to support the growth-enhancing properties of labour force in developing and emerging economies (Roa *et al.*, 2011; Tsani *et al.*, 2013; Cylus & Al Tayara, 2021; Ngoa & Song, 2021).

On whether ICT enhances the impact of labour on growth, the interaction coefficient is negative and statistically significant in three out of four models. Computing the net effect of labour force on growth at the mean values of ICT[7] yields 0.57%, -4.37%, and -3.74%, respectively. Cursory observation indicates that while labour force exerts positive outcomes on growth when interacted with mobile phones, the opposite occurs when fixed telephone is interacted. Similar to the conclusion made on the full sample, these outcomes suggest that mobile phone usage has positive attributes to economic growth relative to fixed telephones. Lastly, the results for upper-middle income countries which are displayed in Table no. 8 provide evidence of a U-shaped ICT relation with economic growth only in columns [1] and [2]. This again validates the ICT leapfrog hypothesis using mobile phones (Ghosh, 2016; Myovella *et al.*, 2020). The impact of labour force is asymmetric (columns 3 and 9). The interaction effect (columns 3 and 9) is also asymmetric and the net impact of labour force at the mean values of ICT[8] is 0.13% and 0.15% which is evident when labour force is interacted with mobile phone usage.

What stands out from the income group analyses is that the U-shaped ICT-growth relation is consistent with mobile phones model. This is an indication that mobile phone usage has more growth-enhancing properties than fixed telephone usage. Also, the growth-stimulating impact of labour force is consistently positive only in high income countries while asymmetric in other groups. Lastly, though the interaction effect is mostly negative across the income groups, the computation of the net effects of labour force at the mean values of ICT reveals that mobile phones is more growth-complementary than fixed telephones. These mixed outcomes justify the engagement of income groups analysis since an aggregated sample may not exactly reveal these intrinsic relationships among the variables and across the sub-groups in the panel.

Table no. 6 – High Income Sample Results

Variables	PSCC-Fixed Effects, Main						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-1.044***	-0.787***	0.747***	-0.0172	0.104***	0.581	-0.892*	-0.843*	-2.144	-0.0174	0.0818	0.459
	(-5.589)	(-10.51)	(3.633)	(-0.580)	(5.222)	(0.647)	(-1.824)	(-1.872)	(-1.534)	(-0.188)	(0.994)	(0.347)
lnICTSQ	0.0292***	0.0231***		0.0100	-0.0176***		0.0263*	0.0256*		0.00876	-0.0133	
	(5.371)	(10.23)		(1.410)	(-4.062)		(1.740)	(1.845)		(0.544)	(-0.919)	
lnNET	-0.0941**	-0.0738**	-0.114***	-0.183***	-0.108***	-0.115***	-0.0536	-0.0397	-0.0837*	-0.113*	-0.0706	-0.0698
	(-2.642)	(-2.302)	(-3.902)	(-4.284)	(-3.471)	(-3.755)	(-0.946)	(-0.795)	(-1.676)	(-1.888)	(-1.335)	(-1.327)
lnGFCF	0.198***	0.176***	0.151***	0.169***	0.156***	0.155***	0.168***	0.157***	0.160***	0.152***	0.143***	0.143***
	(11.43)	(9.714)	(7.148)	(8.505)	(7.698)	(7.957)	(4.780)	(5.051)	(4.633)	(4.309)	(4.617)	(4.586)
EDUC	0.552*	0.687*	0.685**	0.560*	0.737**	0.719*	0.901***	0.840***	0.968***	0.799***	0.811***	0.808***
	(1.922)	(1.976)	(2.051)	(1.973)	(2.144)	(2.027)	(3.158)	(3.340)	(3.476)	(2.738)	(3.153)	(3.142)
IQI	0.0724***	0.0686***	0.0694***	0.0725***	0.0711***	0.0711***	0.0857***	0.0744***	0.0878***	0.0897***	0.0791***	0.0797***
	(3.643)	(3.743)	(3.735)	(3.425)	(3.643)	(3.660)	(5.247)	(5.142)	(5.308)	(5.528)	(5.512)	(5.537)
lnLAB		1.649***	4.569***		1.739***	2.120***		1.600***	-6.370		1.579***	1.943*
		(8.213)	(4.946)		(7.965)	(3.284)		(8.132)	(-1.217)		(7.560)	(1.862)
lnLAB*lnICT			-0.181***			-0.131			0.490			-0.103
			(-3.988)			(-0.642)			(1.518)			(-0.342)
Net Impact			**1.72%**			**2.12%**			**0%**			**1.94%**
Constant	18.74***	9.038***	-9.399**	9.959***	2.030*	0.523	16.79***	9.304**	37.37*	9.655***	2.600**	1.104
	(12.62)	(7.705)	(-2.278)	(38.91)	(1.919)	(0.198)	(4.348)	(2.416)	(1.655)	(24.96)	(2.560)	(0.241)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	338	338	338	337	337	337	303	303	303	301	301	301
Countries	35	35	35	35	35	35	35	35	35	35	35	35
F/Wald Statistic	78040	23986	1.579e+06	33633	882759	437451	437.6	640.9	545.7	427.2	606.3	614.8

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

Table no. 7 – Lower-Middle Income Sample Results

Variables	PSCC-Fixed Effects, Main						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-0.146*	-0.344**	0.808**	-0.0488***	-0.0657***	1.947***	-0.137	-0.644***	1.244	-0.0421**	-0.0439	1.304*
	(-1.857)	(-2.820)	(2.977)	(-3.335)	(-3.455)	(5.087)	(-1.437)	(-3.081)	(1.525)	(-2.082)	(-1.335)	(1.840)
lnICTSQ	0.00418	0.0105**		0.0226***	0.0256***		0.00417	0.0197***		0.0206***	0.0202**	
	(1.701)	(2.698)		(5.062)	(5.061)		(1.362)	(3.053)		(3.290)	(2.246)	
lnNET	0.0205***	0.0314***	0.0274**	0.00396	-0.000165	0.0137***	0.0230	0.0450**	0.0321*	0.00784	-0.000149	-0.00915
	(3.862)	(3.560)	(2.716)	(0.895)	(-0.0309)	(3.553)	(1.405)	(2.367)	(1.672)	(0.564)	(-0.00745)	(-0.298)
lnGFCF	0.0396*	0.0263	0.0227	0.00564	0.0173	0.0294	0.0429	-0.00910	0.0145	0.0261	0.0127	-0.00483
	(1.873)	(1.015)	(0.854)	(0.236)	(0.780)	(1.215)	(1.406)	(-0.250)	(0.398)	(0.911)	(0.319)	(-0.0715)
EDUC	1.189*	1.564***	2.091***	2.564***	2.562***	2.111***	1.347**	1.748***	2.112***	2.253***	2.191***	1.535***
	(1.887)	(3.105)	(3.832)	(11.32)	(9.153)	(5.405)	(2.531)	(3.322)	(3.977)	(4.833)	(4.883)	(3.893)
IQI	0.0712**	0.0656**	0.0587**	0.0407**	0.0507***	0.0591***	0.0603***	0.0609**	0.0668***	0.0478**	0.0797***	0.173***
	(2.627)	(2.703)	(2.530)	(2.579)	(3.096)	(3.964)	(2.581)	(2.547)	(2.694)	(2.420)	(3.217)	(5.790)
lnLAB		0.547**	3.596***		0.382	1.287***		0.198	4.949		-0.0232	0.364
		(2.452)	(3.905)		(1.517)	(4.027)		(0.673)	(1.590)		(-0.0790)	(0.723)
lnLAB*lnICT			-0.194***			-0.444***			-0.297			-0.294*
			(-3.064)			(-5.063)			(-1.536)			(-1.781)
Net Impact			**0.57%**			**-4.37%**			**0%**			**-3.74%**
Constant	7.964***	6.982***	-8.839*	5.936***	4.340***	0.602	7.926***	11.02***	-14.33	6.323***	6.614***	5.579**
	(8.137)	(4.749)	(-2.095)	(31.17)	(4.364)	(0.475)	(8.347)	(4.809)	(-1.084)	(19.95)	(4.774)	(2.472)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	128	120	120	128	120	120	113	106	106	113	106	106
Countries	15	14	14	15	14	14	15	14	14	15	14	14
F/Wald Statistic	365641	232601	18028	6800	20716	582.2	542.1	507.9	456.3	597.8	377.8	219.8

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

Table no. 8 – Upper-Middle Income Sample Results

Variables	PSCC-FE						Random Effects IV-EC2SLS, Robustness					
	Mobile Cellular Subscription			Fixed Telephone Subscription			Mobile Cellular Subscription			Fixed Telephone Subscription		
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]
lnICT	-0.346**	-0.347**	-0.174**	-0.280*	-0.265*	-0.348	0.184	0.201	1.387*	-0.169	-0.205	1.503
	(-2.308)	(-2.370)	(-2.108)	(-2.042)	(-1.897)	(-0.547)	(0.756)	(0.912)	(1.896)	(-0.700)	(-0.847)	(1.076)
lnICTSQ	0.0153***	0.0157***		0.0412	0.0389		-0.00242	-0.00306		0.0274	0.0332	
	(3.416)	(3.765)		(1.650)	(1.501)		(-0.328)	(-0.455)		(0.640)	(0.776)	
lnNET	-0.0468	-0.0413	-0.0505	0.0158	0.00994	0.0121	-0.0139	-0.00598	-0.0321	0.0414	0.0449	0.0557
	(-1.445)	(-1.190)	(-1.374)	(0.937)	(0.450)	(0.494)	(-0.299)	(-0.124)	(-0.619)	(0.834)	(0.876)	(1.006)
lnGFCF	-0.00521	-0.0150	-0.0205	0.00781	0.0120	0.0145	0.0302	0.0269	-0.00431	0.0474	0.0398	0.0508
	(-0.116)	(-0.308)	(-0.428)	(0.225)	(0.328)	(0.418)	(0.763)	(0.634)	(-0.0912)	(1.120)	(0.912)	(1.196)
EDUC	-0.578	-0.567	-0.655*	-0.237	-0.258	-0.279	-0.333	-0.228	0.0349	-0.167	-0.156	-0.0867
	(-1.504)	(-1.503)	(-1.854)	(-0.805)	(-0.831)	(-0.753)	(-1.013)	(-0.677)	(0.0932)	(-0.481)	(-0.445)	(-0.226)
IQI	-0.0333*	-0.0280	-0.0360**	-0.0374**	-0.0402**	-0.0377**	-0.0246*	-0.0210	-0.0216	-0.0235	-0.0206	-0.0248
	(-1.895)	(-1.682)	(-2.232)	(-2.189)	(-2.182)	(-2.305)	(-1.650)	(-1.277)	(-1.288)	(-1.481)	(-1.216)	(-1.485)
lnLAB		0.171	-1.204***		-0.0893	-0.330		0.0341	4.854*		0.115	1.082
		(1.505)	(-3.049)		(-0.530)	(-0.610)		(0.181)	(1.766)		(0.565)	(1.060)
lnLAB*lnICT			0.0867***			0.0710			-0.305*			-0.359
			(4.202)			(0.464)			(-1.761)			(-1.091)
Net Impact			**0.13%**			**0%**			**0.15%**			**0%**
Constant	10.76***	9.946***	11.30***	9.184***	9.551***	10.28***	6.774***	6.419***	-13.01	8.944***	8.520***	4.032
	(9.196)	(6.750)	(7.393)	(27.17)	(11.24)	(4.152)	(3.344)	(3.280)	(-1.126)	(17.24)	(8.553)	(0.881)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	169	168	168	168	168	168	149	149	149	149	149	149
Countries	20	19	19	19	19	19	19	19	19	19	19	19
F/Wald Statistic	5.810e+09	100411	1.311e+06	5.539e+06	85078	371212	406.8	382.9	361.0	341.5	348.1	374.3

Note: *** p<0.01, ** p<0.05, * p<0.1; t-statistics in ( ); PC = GDP per capita; GFCF = gross fixed capital formation; NET = Individuals using the Internet; IQI = Institutional quality index; EDUC = Education index; LAB = Labour force participation.

Source: authors' computations

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study is original and novel as it provides evidence about the role information and communications technology (ICT) plays in the actualization of the 2030 United Nations Sustainable Development Goals most especially SDG 8 which is "Sustained, inclusive and sustainable economic growth, employment and decent work" since labour force is a crucial input of production and economic growth. Given this, we have expanded the frontiers of knowledge to: (i) test the ICT leapfrogging hypothesis; (ii) probe the growth-enhancing impact of labour force participation; (iii) assess the net effect of labour force on economic growth; and (iv) evaluate if the impact is heterogeneous by income groups. To probe the discourse, an unbalanced panel data from 81 countries located in Europe and Central Asia (ECA) and East Asia and the Pacific (EAP) from 2010-2019 is used. Also, to observe if the outcomes differ by the state of economic development, the full sample is divided along four income delineations and analyzed using two robust estimations (PSCC-FE and RE-IV2SLS). Some novel results that emerge are as follows: (i) the ICT leapfrogging hypothesis holds for the full sample and consistent for high income countries; (ii) economic growth is an increasing function of labour force participation; (iii) the net effect of labour force on economic growth is mostly positive with mobile phones as the ICT indicator; and (iv) there are mixed effects across income groups.

Policy recommendations are not far-fetched. With ICT as an enabler of economic growth, we recommend that stakeholders and respective government should channel resources that will enable the population to have unfettered access to ICT apparatus. With labour as a significant growth determinant, we suggest that policies (health and education) be put in place to enable "labour" to become more economically productive. Lastly, the results from the income groups suggest that a uniform policy will be out-of-place. Hence, the state of developments of these countries must be considered in crafting the most-fit policies that will trigger the optimal productivity of ICT and labour force on economic growth. This study is limited by data to test if institutional quality influences the impact of ICT on the labour-growth dynamics. Hence, future studies may want to investigate this nexus subject to data availability.

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ANNEX 1

Table no. 1A – List of Countries and Classifications

S/No.	Country	Region	Group	S/No.	Country	Region	Group
1	Albania	ECA	UMI	42	Malaysia	EAP	UMI
2	Armenia	ECA	UMI	43	Marshall Islands	EAP	UMI
3	Australia	EAP	HI	44	Moldova	ECA	LMI
4	Austria	ECA	HI	45	Mongolia	EAP	LMI
5	Azerbaijan	ECA	UMI	46	Montenegro	ECA	UMI
6	Belarus	ECA	UMI	47	Myanmar	EAP	LMI
7	Belgium	ECA	HI	48	Nauru	EAP	UMI
8	Bosnia and Herzegovina	ECA	UMI	49	Netherlands	ECA	HI
9	Brunei Darussalam	EAP	HI	50	New Zealand	EAP	HI
10	Bulgaria	ECA	UMI	51	North Macedonia	ECA	UMI
11	Cambodia	EAP	LMI	52	Norway	ECA	HI
12	China	EAP	UMI	53	Palau	EAP	HI
13	Croatia	ECA	HI	54	Papua New Guinea	EAP	LMI
14	Cyprus	ECA	HI	55	Philippines	EAP	LMI
15	Czech Republic	ECA	HI	56	Poland	ECA	HI
16	Denmark	ECA	HI	57	Portugal	ECA	HI
17	Estonia	ECA	HI	58	Romania	ECA	UMI
18	Fiji	EAP	UMI	59	Russian Federation	ECA	UMI
19	Finland	ECA	HI	60	Samoa	EAP	UMI
20	France	ECA	HI	61	San Marino	ECA	HI
21	French Polynesia	EAP	HI	62	Serbia	ECA	UMI
22	Georgia	ECA	LMI	63	Singapore	EAP	HI
23	Germany	ECA	HI	64	Slovak Republic	ECA	HI
24	Greece	ECA	HI	65	Slovenia	ECA	HI
25	Guam	EAP	HI	66	Solomon Islands	EAP	LMI
26	Hong Kong SAR, China	EAP	HI	67	South Korea	EAP	HI
27	Hungary	ECA	HI	68	Spain	ECA	HI
28	Iceland	ECA	HI	69	Sweden	ECA	HI
29	Indonesia	EAP	LMI	70	Switzerland	ECA	HI
30	Ireland	ECA	HI	71	Thailand	EAP	UMI
31	Italy	ECA	HI	72	Timor-Leste	EAP	LMI
32	Japan	EAP	HI	73	Tonga	EAP	UMI
33	Kazakhstan	ECA	UMI	74	Turkey	ECA	UMI
34	Kiribati	EAP	LMI	75	Turkmenistan	ECA	UMI
35	Kosovo	ECA	LMI	76	Tuvalu	EAP	UMI
36	Kyrgyz Republic	ECA	LMI	77	Ukraine	ECA	LMI
37	Lao PDR	EAP	LMI	78	United Kingdom	ECA	HI
38	Latvia	ECA	HI	79	Uzbekistan	ECA	LMI
39	Lithuania	ECA	HI	80	Vanuatu	EAP	LMI
40	Luxembourg	ECA	HI	81	Vietnam	EAP	LMI
41	Macao SAR, China	EAP	HI				

Note: EAP = East Asia and the Pacific; ECA = Europe and Central Asia; HI = High Income; LMI= Lower-middle Income; UMI = Upper-middle Income.

Source: authors' compilations

Table no. 1B – Variance Inflation Factor

		Mobile Phones Models			
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
EDUC	3.71	0.269473	EDUC	3.6	0.277528
lnNET	3.3	0.303372	lnNET	3.34	0.299093

		Mobile Phones Models			
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
IQI	2.61	0.383647	IQI	3.21	0.311708
y8	1.9	0.52642	y8	1.92	0.520256
y7	1.87	0.534747	y7	1.9	0.526025
y6	1.84	0.542434	y6	1.87	0.53603
y5	1.83	0.54525	y5	1.85	0.540818
y4	1.81	0.551753	y4	1.82	0.549002
y3	1.81	0.55224	y3	1.81	0.551297
y2	1.79	0.558609	y9	1.81	0.552538
y9	1.76	0.567816	y2	1.79	0.558278
y10	1.67	0.597376	y10	1.72	0.58177
lnGFCF	1.18	0.846752	lnLAB	1.38	0.725742
lnMOB	1.12	0.891127	lnGFCF	1.18	0.848123
			lnMOB	1.15	0.869338
Mean		**2.02**	**Mean**		**2.02**
		Fixed Telephones Models			
Variable	**VIF**	**1/VIF**	**Variable**	**VIF**	**1/VIF**
EDUC	3.78	0.264714	EDUC	3.66	0.273328
lnNET	3.34	0.299615	lnNET	3.37	0.296338
IQI	2.59	0.386544	IQI	3.14	0.318423
y8	1.91	0.523268	y8	1.94	0.51417
y7	1.89	0.529528	y7	1.92	0.520958
y6	1.86	0.538785	y6	1.88	0.532349
y5	1.84	0.542402	y5	1.86	0.537949
y3	1.81	0.55141	y9	1.83	0.546308
y4	1.8	0.554382	y3	1.82	0.550347
y2	1.79	0.558538	y4	1.81	0.551392
y9	1.78	0.56221	y2	1.79	0.558087
y10	1.69	0.591421	y10	1.74	0.574837
lnFTEL	1.24	0.807776	lnLAB	1.33	0.749375
lnGFCF	1.18	0.850761	lnFTEL	1.2	0.832059
			lnGFCF	1.18	0.850459
Mean		**2.04**	**Mean**		**2.03**

Note: y2, y3,…,y10 are Year Dummies.

Source: authors' computations

Notes

[1] Ericsson and the Earth Institute Report https://www.ericsson.com/assets/local/news/2016/05/ict-sdg.pdf.

[2] The labour force participation rate is the fraction of the population within a particular age group either working or looking for work. In the rest of the paper, "labour force participation" and "labour" are used interchangeably.

[3] See Annex Table 1A for the list of countries and their respective classifications.

[4] The mean values of lnMOB and lnFTEL for the full sample are 15.615 and 13.891, respectively.

[5]Non-significant interaction term implies that the coefficient is significantly not different from zero. Hence, the marginal effect equates to the net effect.

[6]The mean values of lnMOB and lnFTEL for high income countries are 15.735 and 14.406, respectively.

[7]The mean values of lnMOB and lnFTEL for lower-middle income countries are 15.578 and 12.732, respectively.

[8] The mean values of lnMOB and lnFTEL for upper-middle income countries are 15.426 and 13.858, respectively.