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Relationship between Information and Communication Technologies and Sustainable Development: Fresh Evidence from Group of Seven (G-7) Countries

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ABSTRACT

There is ongoing discussion about the use of information and communication technologies (ICT) to promote sustainable development. While one side fiercely advocates using ICT technologies to drive and carry out sustainable development, others passionately struggle to highlight their many drawbacks. The present study adds to ongoing discussion by estimating the effect of ICT on sustainable development in G-7 economies over 1995-2020 period, which is an unreached area in the literature. The study also holds its novelty by considering Adjusted Net Savings (ANS) for measurement of sustainable development. As cross sectional dependence (CSD) and slope heterogeneity are present in data, second-generation panel estimation technique Cross sectional Augmented Distributed Lag Model (CS-ARDL) is used for the long run and the short run estimation. The findings assert that ICT technologies have positive effect on sustainable development in G-7 countries. In addition, the study also finds the positive contribution of renewable energy and negative contribution on non-renewable energy in sustainable development of the selected countries. The study recommends the governments to adopt effective policies to implement and improve infrastructure quality in terms of digital technologies to achieve sustainable development in selected economies.

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1. Introduction

A comprehensive 2030 Sustainable Development Agenda was proposed by the world leaders at the United Nations Summit on Sustainable Development in 2015 that aims to "move the world onto a resilient and sustainable path" and is "a plan of action for planet, prosperity and people" (Kostoska & Kocarev, 2019). Sustainable development refers to "the development that fulfills the current needs without compromising the potential for future generations to satisfy their respective needs". Sustainable development is the process of addressing human needs while safeguarding the environment and natural resources for coming generations (Jayaprakash & Radhakrishna Pillai, 2022). Sustainable development creates harmony between three aspects i.e., economic, social and environmental and presently developed and developing countries are required to make use of all the tools required to carry out and deliver the essential modifications to achieve sustainable development goals (Kostoska & Kocarev, 2019).

Achieving these "reach" goals would require societies to change far more quickly and significantly than they have in the past. Digital technologies are a crucial platform for the sustainable development goals and a key acceleration technology that can move nations on to the sustainable development trajectory. Electronic networks with complicated hardware and software connected by a wide range of technical protocols are included in ICTs by definition. It includes providing internet access, telecommunications hardware and software, information technology hardware and software, media and broadcasting, libraries and information centres, businesses that provide commercial information, network-based information systems, and other related communication and information technology activities (Paul & Uhomoibhi, 2012). There are many hopes, fantasies, and myths connected to the increasing supply, use, and availability of ICT technologies. ICT has improved people's quality of life over the past few decades, and societies worldwide are today more interconnected than ever. Availability to digital media, such as smart phones, social media and internet, has recently had a huge impact on daily social interactions as well as being a useful instrument for sustainable development. According to a statement from the International Telecommunications Union, "ICT is an appropriate tool for the sustainability if ICT spread is clearly linked with a country's capacity for sustainable development"(Latif et al., 2017).

Without any doubt, ICT has the capability to significantly impact all three dimensions of sustainability like ICT has made tremendous advances in human relationships and brought about a number of technologies that appear to stimulate economic growth and lessen wealth inequality, encourage financial development, encourage inclusive education (Avom, Nkengfack, Fotio, & Totouom, 2020). Although these accomplishments are admirable, they cannot obscure the reality that ICT might also be used as a way to achieve all sustainable development goals. In fact, the literature contains two opposing claims. The first postulates that ICT use could slow down environmental degradation by increasing energy efficiency, productivity, and the creation and renewable energy use (Asongu, 2018; Shobande & Asongu, 2022; Zhang & Liu, 2015). Also, this beneficial outcome results from increased productivity, which makes it possible to reduce pollution by designing smarter cities, , energy infrastructure, transportation networks and industrial activities (Avom et al., 2020). The second claim makes the connection between increased ICT adoption and increased pollution. The adverse effects of ICT manifest themselves via a variety of avenues, including a rise in industrial productivity, increased energy use, globalization, as well as a more prosperous financial structure (Batool, Raza, Ali, & Abidin, 2022; Khan & Ximei, 2022; Park, Meng, & Baloch, 2018).

These conflicting views about ICT technologies and sustainable development nexus motivate the researchers to dive again into exploration of this nexus. The goal of the current research is therefore to assess how ICT may affect sustainable development in G-7 countries over 1995-2020 period. The research adds to the body of literature in following ways: First, the present study diverges from previous research by examining the impact of ICT technologies on sustainable development using the composite measure for sustainable development i.e., ANS (detailed description of ANS is provided in section 3). Previous research has focused on the relationship between ICT and specific sustainable development component. Second, the study focuses on G-7 (Canada, Germany, France, Japan, Italy, the USA and the UK) as this area is not researched yet to explore the above mentioned nexus. G-7 is a group of developed nations having a sharp acceleration in economic growth throughout the recent recession. Early in 2018, these countries accounted for roughly 60% of the world's wealth, while contributing around 45.8% of nominal GDP and 31% of GDP based on purchasing power parity and home to 10% or 770 million people of the global population. Despite rapid growth, due to their significant contribution to world energy use, G-seven are accountable for the unsustainable state of the environment and include world's top carbon emitting countries. The G-seven economies are going through a period of digitalization and knowledge transition and are more knowledge based and skilled countries as compare to developing economies (Khan & Ximei, 2022). Earlier studies have ignored the effect of ICT technologies on sustainable development for G-7 countries We have significant policy implications for the governments of the G-seven economies by focusing on these aspects. Third, the study holds its novelty in methodological aspect by applying second generation CS-ARDL estimation which previous studies did not use to empirically assess ICT and sustainable development nexus.

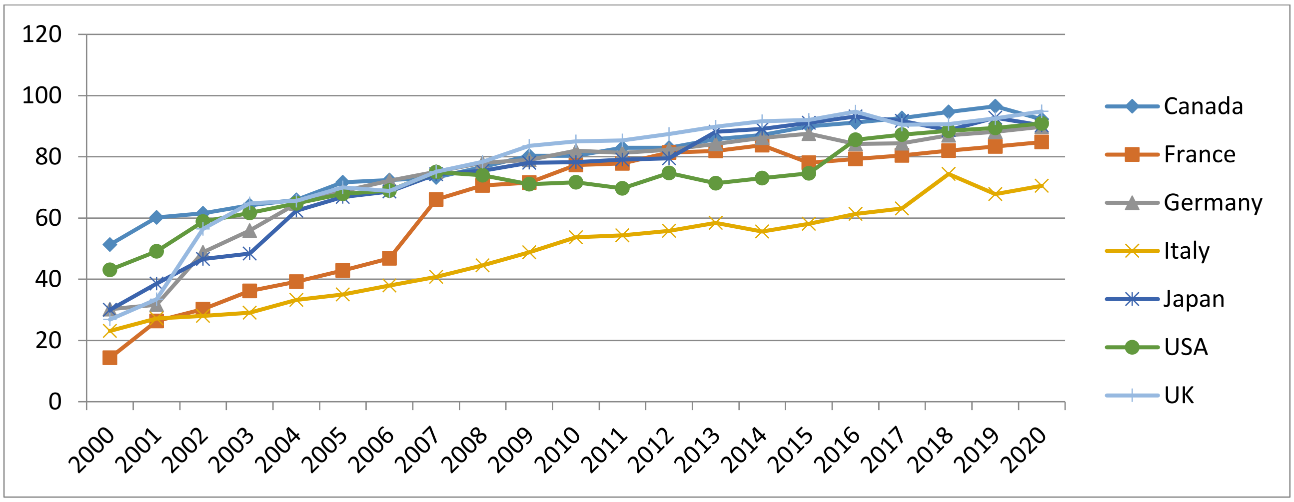

Figure 1: Internet penetration in G-7 countries over the 2000-2020 period.

The next sections of the study are organized in following order: Next section 2 gives review of existing literature. Section 3 includes data and methodology. Results and discussions are provided in section 4, which is followed by conclusion and policy recommendations in section 5.

2. Review of Previous Literature

The existing literature about the nexus between ICT technology and sustainable development mostly concentrates on how technology affects the specific goals that the UN has emphasized. In this regard, previous literature has mainly considered three main themes: the environment, society, and the economy. Like, Avom et al. (2020) analyzed the effect of ICT on CO2 emission by taking into consideration the Sub-Saharan African countries and posited that ICT had positive direct as well as indirect role in increasing CO2 emission in these countries. Chatti (2021) studied the relationship ICT and CO2 emission in 43 countries and the results of GMM estimation found that ICT significantly reduced CO2 emission. Alataş (2021) also tried to explore the nexus between ICT and CO2 emission by taking into consideration the panel of 93 countries. According to the findings of empirical analysis, ICT was found to have positive effect on CO2 emission. The impact of ICT on social development has been debated by several authors in the second body of literature. Mobile phones and technology have altered lives by cutting-edge services and applications. So, it is not unusual that current studies have drawn attention to the effects of ICT on both human and economic well-being. In this regard, a number of researches have examined social sustainability through the lens of comprehensive human development. For instance, Asongu and Odhiambo (2020) analyzed the nexus between ICT and human development in Sub Saharan African economies and found that ICT had positive effect on human development through the lens of CO2 emission and trade. In another study, Asongu and Odhiambo (2019) assessed the role of ICT on education quality in these countries by using Instrumental Quantile Regression and 2SLS and it was concluded that increased ICT penetration was responsible for reducing poor quality education. Alfaro Cortés and Alfaro Navarro (2011) considered the ICT and human development and economic growth nexus in 27 EU countries and concluded that ICT promoted human development and economic growth. In case of 123 developed and developing countries, Appiah-Otoo and Song (2021) explored the nexus between economic growth and ICTs and found that ICT increased economic growth in both panels of countries. in case of OECD Nair, Pradhan, and Arvin (2020) attempted to analyze the association between R&D, ICT and economic growth. The findings of Vector Error Mechanism (VECM) revealed that ICT and R&D affected economic growth positively in OECD economies.

In continuation, Jayaprakash and Radhakrishna Pillai (2022) considered a global panel to study the association between all three measures of sustainable development and ICT. The results of Seemingly Unrelated Regression estimation reveal that ICT had positive impact on all human development, economic growth as well as environmental performance. In addition, some studies are also present in the literature that consider some comprehensive indicator for sustainable development like, Nchofoung and Asongu (2022) considered sustainable development index as measure for sustainable development and examined the impact of ICT on sustainable development in a global panel of 140 economies. Applying various panel estimation approaches, authors found that ICT contributed positively in sustainable development irrespective of income level and geographical location. Pardi, Sahudin, Majid, Junos, and Ali (2021) considered ANS as measure for sustainable development to analyze the nexus between sustainable development and ICT in Asian countries. Generalized Least Square Fixed Effect estimation was applied to carry out empirical analysis. The findings established that mobile subscriptions and internet both contributed positively in sustainable development of Asian countries. Thus, we formulate the research hypothesis as:

H1: There is significant contribution of ICT on sustainable development.

2.1 Research Gap

Despite long standing literature on ICT and sustainable development, some gaps are identified and filled in by the current study. First, a herding behavior is observed among previous studies in estimation of sustainable development by any individual indicator (environmental, economic or social). Only a few studies are available that considered all three measures or any comprehensive indicators that encompasses all measures of sustainable development. In addition, no previous study paid attention to G-7 countries to explore this nexus. Therefore, the current study, by filling in these gaps, is going to be novel and significant contribution in the existing literature.

3. Data and Methodology

The present research aims at estimating the role of ICT technologies on sustainable development in G-7 countries over 1995-2020 periods. The research develops a comprehensive index of three distinct technologies using Principle Component Analysis technique: fixed broadband subscriptions (per 100 people), fixed mobile phone subscriptions (per 100 people) and fixed telephone subscriptions (per 100 people). The dependent variable is sustainable development measured by ANS following (Güney, 2019; Kamoun, Abdelkafi, & Ghorbel, 2019); Pardi et al. (2021). In addition, model includes renewable energy and non-renewable energy to avoid omitted variable bias. The details of variables are given in Table 1.

The model for empirical estimation is specified as:

$$SD_t = \beta_0 + \beta_1 ICT_t + \beta_2 RE_t + \beta_3 NRE_t + \varepsilon_t \quad (1)$$

3.1 ANS Calculation

The relevant adjustments are made to the gross national saving to obtain the ANS: (1) In order to calculate net national savings, the consumption of generated capital is subtracted (DK); (2) To account for the human capital investment, the government's existing operational spending on education is also contributed (GEE). (3) The reduction in asset values related to extraction and depletion is expressed by subtracting the loss of natural capital (mineral, net forest and energy), (DNC) (4) Damages from particulate and carbon dioxide emissions are subtracted (CO2); (5) Divided by the GNI, which can be represented by the following equation:

$$\frac{ANS = GNS - DK - DNC + GEE - CO2}{GNI}$$

Where, GNS are determined by subtracting net transfers from gross national income and adding total consumption (Castro & Lopes, 2022).

Table 1
Measurement and Data Sources

Variables/Series	Acronym	Proxy	Data Source
Sustainable development	SD	Adjusted Net Savings (% of GNI)	WDI
ICT Technologies	ICT	Fixed telephone subscriptions (per 100 people), Fixed mobile phone subscriptions (per 100 people), Fixed broadband subscriptions (per 100 people)	WDI
Renewable energy	RE	Renewable energy use (quadrillion btu)	EIA
Non-renewable energy	NRE	Petroleum and other liquids use (quadrillion btu)	EIA

3.2 Estimation Methodology
3.2.1 Preliminary tests

We need to assess whether CSD exists between the series in order to assess how ICT affects sustainable development. The null hypothesis claims that the variables are equally distributed and are independent. A model for CSD analysis has been proposed by (Pesaran, 2004). Below is a presentation of the CD equation:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}\right) \sim N(0,1)i, j \quad (2)$$

And here, denotes the correlation between the variables' error term. The following are the test's hypotheses: H0: no CSD and H1: CSD is present. To see if the variables evaluate same thing or different effects, the homogeneity slope is also tested. The null hypothesis assumes slope homogeniety. Moreover, the delta and adjusted delta tests are carried out as suggested by Swamy (1970) to check for variable heterogeneity. The corresponding model equation is as follows:

$$\tilde{\Delta}_{SH=} (N)^{\frac{1}{2}} (2K)^{-1/2} (\frac{1}{N}\tilde{S}\text{-k}) \quad (3)$$

Where, S denotes Swamy model. The Δ statistic is adjusted for normal distribution as follows:

$$\tilde{\Delta}_{ASH=} (N)^{\frac{1}{2}} (\frac{2k(T-k-1)}{T+1})^{-\frac{1}{2}} (\frac{1}{N}\ \widetilde{S} - k) \quad (4)$$

Following the CD estimate, the stationarity properties are evaluated using second generation CIPS and CADF unit root tests proposed by (Pesaran, 2007). On account for the presence of first order integration order, cointegration test introduced by (Westerlund, 2007) is applied. These tests are robust when CSD and slope heterogeneity exist in data.

3.2.2 CS-ARDL Analysis

Using CS-ARDL approach, the long-run and short run coefficients are determined. Because of strict assumptions about slope heterogeneity, CSD and endogeneity, this technique is superior as compare to other estimation methodologies. In previous researches, standard techniques are used to assess the variables influencing sustainable development and ICT technologies. These conclusions can be disputed on the basis that different model variables may produce interdependent cross- sectional error terms. ICT technologies and sustainable may be impacted by unobserved common model aspects. Therefore, precise estimations might be achieved by combining explanatory factors with unobservable common components of sustainable development for different cross sections. CS-ARDL estimation introduced by (Chudik & Pesaran, 2015) is used in the study owing to its stringent assumptions. Equation of CS-ARDL can be expressed as follows:

$$\Delta Y_{it} = \varphi_i + \sum_{l=1}^{p} \varphi_{it} \Delta Y_{i,t-1} + \sum_{l=0}^{p} \varphi_{il}' EXV_{s,i,t} + \sum_{l=0}^{1} \varphi_{il}' \overline{CSA}_{i,t-1} + \varepsilon_{it} \quad (5)$$

Where CSA denotes cross sectional averages and $\overline{CSA}_t = (\Delta\bar{Y}_{t,} \overline{EXV}_{s,t})'$ that is explanatory variables are denoted by EXV.

4. Results and Discussion

First of all, Table 2 presents CSD and slope heterogeneity test findings. The findings indicate that CSD is present among all series as we reject H0 of no CSD. Moreover, the findings of slope heterogeneity test reveal the heterogeneity of slope parameters.

Table 2
CSD and Slope Homogeneity Test Results

CSD Test	
Variable	**Test Stat/ (p-values)**
SD	18.311*** (0.000)
ICT	13.214*** (0.000)
RE	29.232*** (0.000)
NRE	36.430*** (0.000)
Slope Heterogeniety Test	
Delta Tilde	45.087***(0.000)
Adj. Delta Tilde	12.333**(0.000)

Note:***P<0.005

Next second generation tests namely CADF and CIPS unit root tests are applied that indicate that all of our variables are stationary after first difference (Table 3). This necessitates the estimation of long run cointegration and it is found that long run co integration is present among series. The corresponding results are presented in Table 4.

Table 3
Unit Root Tests

	CIPS		**CADF**	
Variables	**Level**	**First Difference**	**Level**	**First Difference**
SD	-1.125	-3.840***	-1.446	-1.777***
ICT	-1.835	-2.637***	-1.415	-3.141***
RE	-2.430	-2.995***	- 2.340	-3.188***
NRE	-1.238	-3.452***	-1.057	-4.155***

Table 4
Cointegration Test Results

Test Statistics	Z-Value	P-Value
G_t	-2.533	0.000
G_a	-1.934	0.037
P_t	-2.631	0.009
P_a	-2.428	0.090

After these preliminary estimations, CS-ARDL long run and short run parameters are evaluated and outcomes are reported in Table 5. According to estimation, all parameters are statistically significant that effect sustainable development either positively of negatively.

Table 5
CS-ARDL

Dependent Variable SD	Short Run Results		Long Run Results	
	Coefficients	prob-values	Coefficients	prob-values
ICT	0.166***	0.023	1.283***	0.000
NRE	-0.149***	0.009	-0.341***	0.005
RE	0.716**	0.076	0.409***	0.004

Where **= p>0.05 & ***=p<0.05

First of all, according to the findings ICT technologies have significant and positive impact on sustainable development in the long run and the short run. This finding is in line with Nchofoung and Asongu (2022) for global panel, Latif et al. (2017) for South Asian economies, Jayaprakash and Radhakrishna Pillai (2022) for global panel of 80 countries. The finding implies that ICT technologies might facilitate fair human development, promote economic expansion, enhance environmental quality, and lessen inequality (Njangang, Beleck, Tadadjeu, & Kamguia, 2022). When ICT is successful in improving the environmental, social and economic components, it contributes to sustainable development. Technology provides the ideal platform for proper teaching on the SDGs via the internet and phones. It boosts economic activity and economies of scale, as well as facilitating investment and trade opportunities. As a result, the economy now generates a higher amount of income that may be used to pay for the Sustainable Development Goals (Nchofoung & Asongu, 2022).

Second, renewable energy is also revealed to impact sustainable development positively and significantly in G-7 economies in the short and the long run. This result strongly validates the fulfillment of 7th goal of sustainable development i.e., affordable and clean energy and strongly in line with previous studies of Behboudi, Mohamadzadeh, and Moosavi (2017) for Iran, You (2011) for China, Hassoun and Hicham (2020) for OECD, Güney (2019) for developing countries and Vo (2021) for Southeast Asian countries. The finding implies that addition of these energy resources can be beneficial for these nations and improve their economic situation. It will also produce more environmentally friendly energy and might be able to supply all of the energy needs in the future.

Third, in contrast to RE that affects sustainable development positively, NRE has negative impact in the short run and the long run on sustainable development. these findings suggest using RE more as compare to NRE as the later proves to be an obstacle in achieving sustainable development. the findings are helpful for South Asian countries to achieve sustainable development as these countries are heavily dependent on non renewable energy resources. from previous studies, the findings of (Güney & Kantar, 2020) for OECD economies, (Güney, 2021a, 2021b) for OECD and high income countries and (Güney, 2021c) for 35 countries strongly support our finding regarding sustainable development and non renewable energy nexus. But (Saboori & Soleymani, 2011) in case of Iran is in contrast with as NRE contributed positively in sustainable development in their study.

5. Conclusion and Policy Recommendations

The major problem that contemporary society is facing is finding a way to balance the objectives of sustainable growth and limiting environmental impact. In view of the proposed sustainable development goals, countries have long considered developing adequate policies like upgrading and integrating ICT technologies to support sustainable development. The goal of the present research is to empirically estimate the nexus between ICT technologies and sustainable development in G-7 countries over 1995-2020 period. Second-generation panel estimations including CSD, slope heterogeneity, unit root and long run cointegartion are applied. For long term and short term coefficient estimation, CS-ARDL estimation approach is used because of the CSD and slope heterogeneity issues are present in data. The findings assert that ICT impacts sustainable development positively both in the long run and the short run. Moreover, the positive role of renewable energy in achieving sustainable development is also found whereas non renewable energy has negative effect on sustainable development in G-7 countries. Thus the study concluded that ICT technologies accrue many benefits of sustainable development.

On the basis of these findings, it is recommended that G-7countries should assemble digital policies for modern digital applications, produce skilled laborers, and advance e-culture in the area. The governments of the selected countries are advised to pay attention for the improvement of the connectivity and infrastructure superiority in terms of ICT and digital technologies. In addition, there should be reduction in cost of different digital equipments and their application. Finally, we advise governments to consider resources other than traditional economic ones, such as digital human capital, which could help them achieve sustainable development. The synergy between environmental protection and socioeconomic growth can eventually be established and maintained well with a solid economic basis and competent management of the digital economy environment.

Authors Contribution
Sobia Hanif: literature search, data collection, methodology, drafting
Abou Bakar: critical revision, incorporation of intellectual content
Muhammad Atif Nawaz: study design & concept, data analysis, data interpretation

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