Visiting Fellow Program

Exploring the Development, Environment, Trade, and Technology Nexus in the CAREC Region:

A Path Analysis from Technology to Sustainable Development

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Visiting Fellow Program

Exploring the Development, Environment, Trade, and Technology (DETT) Nexus in the CAREC Region: A Path Analysis from Technology to Sustainable Development

by Dr. Rabia Nazir

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Disclaimer

Under the Visiting Fellow Program, the CAREC Institute issued research grants in 2023 to support scholars and researchers to produce targeted knowledge products that would add to the body of knowledge on regional cooperation in the CAREC region.

Scholars were encouraged to conduct research on CAREC integration topics and carry out comparative analyses between (sub)regions to obtain insights for promoting and deepening regional integration among CAREC member countries particularly, as anticipated in the CAREC 2030 strategy and stated operational priorities.

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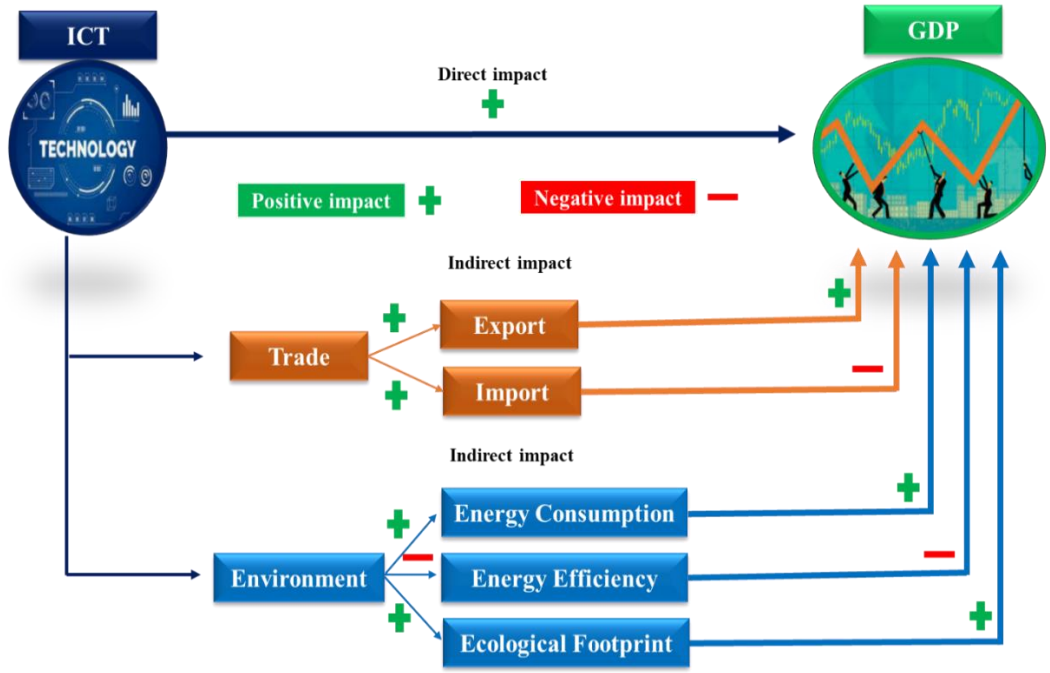
Abstract

The information and communication revolution has increased the integration of the global economy. National reliance on international supply chains and environmental quality fueled by digital platforms has increased. As a result, international trade, environmental quality, and information and communication technology (ICT) appear to have taken the lead in driving sustainable development (SD). In this study, we examine the veracity of this logical claim. Using trade and environmental quality as mediating factors, the study examines the direct and indirect effects of ICT on SD (proxied by GDP). It uses a structural equation method to investigate the relationship between trade, environmental quality, ICT, and SD using data on the CAREC economies from 2000 to 2022. The findings show that the total impact of ICT on GDP is positive; ICT has a positive impact on trade, energy consumption, and ecological footprint but a negative impact on energy efficiency. In turn, all these variables—except for energy efficiency—have positively impacted GDP. The study's conclusions have important ramifications directly through ICT to improve SD and indirectly through reducing environmental degradation and improving trade. This study extends the prior literature by examining the moderating effect of trade and environmental quality on the relationship between ICT and SD.

Keywords: ICT; trade; environment; economic growth; sustainable development; CAREC economies

Graphical Abstract



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1. Introduction

With the technology revolution during the past ten years, the global economy has become increasingly integrated. Countries are becoming more dependent on the global supply chain, which is fueled by digital platforms (Hedberg & Šipka, 2021). Modern technology affects almost all economic activities, including trade, marketing, and the environment; however, it improves access to information, employs natural resources, and boosts economic growth (Piscicelli, 2023). In this advanced age, information technology should foster a knowledge-based society. E-governance (electronic governance or EG) integrates ICT into all activities to help the government meet local needs. It reduces corruption, boosts transparency and convenience, and ultimately promotes GDP growth. ICT has a direct impact on economic growth through several significant dimensions. First, it aids manufacturers in producing goods and services with added value. Second, improved productivity in the ICT industry boosts overall workplace effectiveness. Third, by embracing ICT, the production and efficiency of many economic areas—such as agriculture, manufacturing, and service—can boost their output and efficiency (Awad & Albaity, 2022).

Scholarly literature discusses several ways in which ICT boosts economic growth. Even without a comprehensive proposal, the function of ICT shares some common ground with economic growth. ICT generally influences economic development both directly and indirectly. It affects GDP directly by increasing productivity, while indirectly through materializing externalities (Fernández-Portillo et al, 2020). It indirectly affects GDP by creating jobs, maximizing revenue, reducing transaction costs, rapidly creating knowledge, reducing price fluctuations and irregularities, encouraging market efficiency, and encouraging investment (Asongu, 2015; Haftu, 2019). Numerous studies have emphasized the direct and positive association between ICT and GDP (Appiah-Otoo & Song, 2021; Arvin et al, 2021; Hussain et al, 2021; Odhiambo, 2022). However, many past studies neglected the significance of the indirect crucial elements that ICT may use to influence per capita GDP growth.

There are few instances where different indirect channels are explored between ICT and growth. For example, Skorupinska and Torrent-Sellens (2017) proposed complementary innovations; Awad and Albaity (2022) used foreign direct investment (FDI), trade openness, local investment, education, political institutions, and inflation; and Breitung et al (2022) and Qureshi and Najjar (2017) proposed education as a mediating channel between ICT and growth. Since ICT affects almost all walks of socioeconomic development, its impact on some other important indicators such as trade and environment must also be explored. However, there is currently no evidence in the literature to support the idea that environmental quality and trade have a mediating effect on the relationship between technology and growth.

As far as trade channels mediating the relationship between ICT and growth is concerned, ICT may affect trade in numerous ways and thus, in turn, may have contrasting implications for growth. ICT fragments the global value chain and moves elements of the production process to different countries. ICT allows firms to exchange information globally, interact just-in-time with clients and suppliers, and offer services quickly and efficiently (Ahmed et al, 2022). In many circumstances, ICT delivers services and may boost trade flows. It may lower market entrance costs, boosting exports (Evans & Mesagan, 2022). It speeds up information acquisition and transmission, improving planning efficiency and accuracy. Thus, international trade should increase. However, despite the intuitively plausible implications outlined earlier, it is unclear how ICT will alter exports and imports and subsequently growth dynamics through this channel.

Regarding environmental channels, the indirect impact of ICTs on GDP could be either favorable or detrimental. ICT has the potential to reduce transaction and travel costs associated with CO_2 emissions in households and enterprises. Improved decision-making, transportation infrastructure,

vital infrastructure, industrial activities, and energy efficiency will all reduce CO_2 emissions (Usman et al, 2021). ICT adoption, on the other hand, has a high environmental cost. The ICT industry's share of CO_2 emissions is rising because the production of ICT-related materials pollutes the environment (Chen et al, 2019) and the increased use of the Internet, mobiles, computers, and so on has increased energy demand (Chien et al, 2021), which is the main cause of environmental degradation. Owing to harsh weather, increasing sea levels, droughts, health issues, and more, rising greenhouse gas emissions threaten the future (Abdouli & Hammami, 2017). Thus, environmentalists and scholars are investigating measures to reduce carbon emissions and boost GDP.

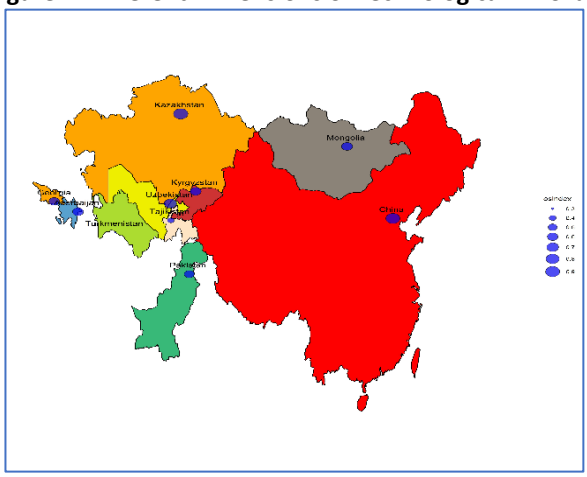
The goal of this study is to simulate a technology-SD nexus for the Central Asian Regional Economic Cooperation Program (CAREC) economies. 'Good neighbors, good partners, and good prospects' is the motto of the CAREC program, a regional economic cooperation among 11 Asian countries: Afghanistan, Azerbaijan, China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan. The goal of the CAREC regional strategy is to increase trade, finance, and economic cooperation among nations. Between 2001 and 2020, the CAREC countries invested USD40 billion in 213 projects. Additionally, the CAREC includes nations like China, which rank among the world's largest carbon emitters. China emits 10.67 billion metric tons of CO_2. Increased coal use in China emitted 11.9 billion tons of CO_2 in 2021, 33 percent of the global total (IEA, 2021). As a result, the deployment of clean energy and sustainable economic growth are two crucial issues for the CAREC, and its members need to focus more on these areas. Figure 1 indicates the different dimensions of ICT in the CAREC countries.

CAREC members use fossil fuels nearly exclusively and have unsustainable economic frameworks (Qadir & Dosmagambet, 2020). With these environmental and trade problems characterizing the CAREC countries, it is important to pay attention to the strategies aimed at sustainable development while addressing the environmental and trade issues. Henceforth, the CAREC countries need to find key drivers for sustainable development that have the potential to affect all these interlinked issues simultaneously. With this as a backdrop, ICT seems to be a viable solution with significant implications for environment, trade and growth.

This paper's goal is to adopt a different perspective from earlier research on the connection between technological advancement and SD. It examines whether technology serves as a catalyst to enhance the influence of trade and environmental quality and, crucially, how these factors affect EG in the CAREC countries. Additionally, the direct effects of technology on EG are examined. This study addresses three key research questions: (1) How does technology (specifically, e-governance) affect sustainable development in the CAREC countries? (2) How does technology indirectly affect regional sustainability through environmental quality? and (3) How does technology indirectly affect regional sustainable development through the trade channel? We use data from ten CAREC economies from 2000 to 2022 and structural equation modeling (SEM) to quantify and answer the research questions outlined earlier. In contrast to the existing literature on ICT, we used comprehensive measures of technological innovation including e-governance index, subindices of e-participation, online services and tele-infrastructure, and fixed telephone subscriber.[1] The study reveals that ICT significantly impacts GDP directly and indirectly, indicating that e-governance facilitates trade in the CAREC region. Exports have a positive impact, while imports have a negative impact. The total impact of ICT on GDP, even via imports, is positive, suggesting an export promotion strategy.

[1]These measures are used with the traditional measure that is fixed telephone subscribers to compare and contrast study findings with existing literature.

Figure 1: Different Dimensions of Technological Innovation in the CAREC Countries



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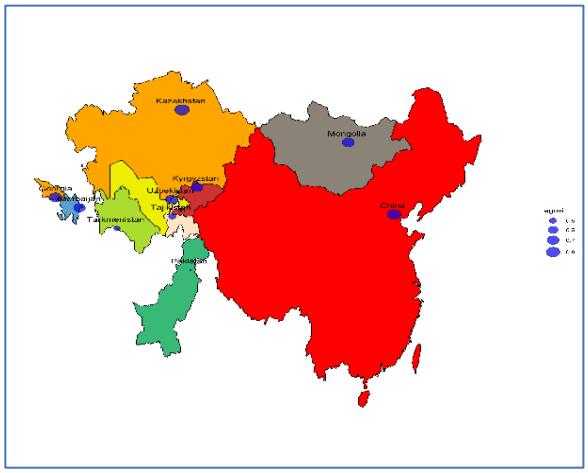
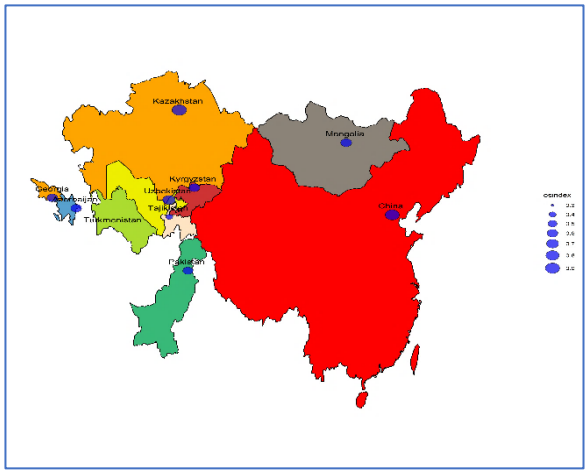
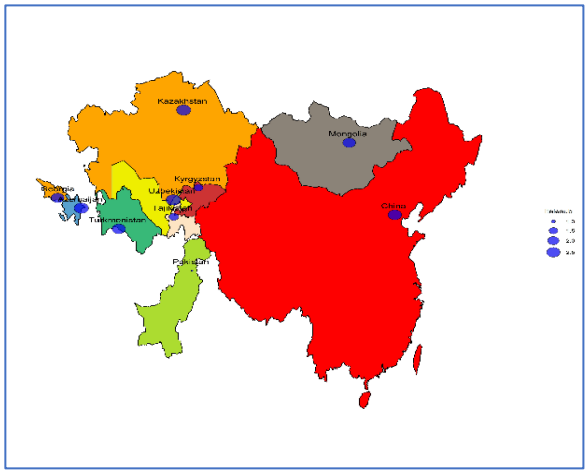


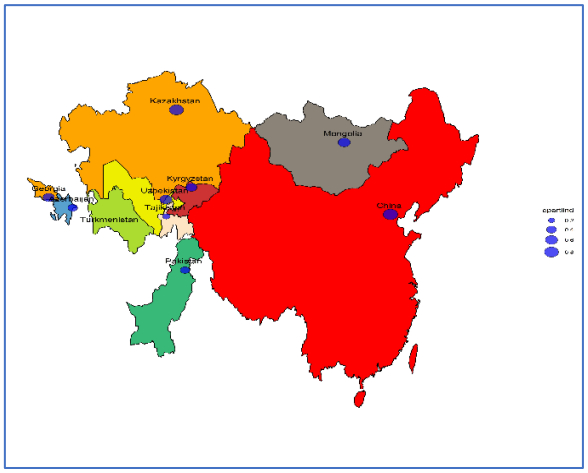
E-Government Development Index



Online Service Index



E-Participation Index



Telephone Subscriptions

Source: Author construction

The CAREC region is experiencing higher energy consumption and a greater ecological footprint (EFP) owing to ICT use, contributing positively to its GDP. However, the energy consumption in the region exhibits energy inefficiency. Energy consumption, its inefficiency, and resultant ecological footprint are interlinked factors. The swift advancement of technology and utilization of ICT is leading to increased energy usage in the region. For example, the energy demand in the CAREC countries reached 204 million tons of oil equivalent in 2020 and is expected to increase to a range of 254 million tons to 290 million tons by 2030. Electricity is a significant contributor to overall energy

consumption, although the use of natural gas is projected to increase because of its prevalent use in power generation, as well as in residential and industrial sectors. Presently, wind and solar energy sources are merely 6 percent of the region's total installed capacity. Hence, increased energy consumption, coupled with a strong dependence on non-renewable energy sources, results in a larger ecological impact.

Furthermore, a number of CAREC countries are currently classified among the 20 least energy-efficient economies in the world owing to their reliance on the outdated energy infrastructure inherited from the Soviet Union era. Energy losses in the electrical sector can reach up to 20 percent in 2023 (ADB, 2023). In addition, many countries employ non-renewable forms of energy for resource extraction, which are both energy-inefficient and have a substantial impact on emissions and energy inefficiency in the region (ADB, 2023). The region must address environmental degradation issues and promote eco-friendly practices to achieve sustainable development.

The study also reveals that ICT boosts international trade by improving communication, e-commerce, and supply chains. ICT improves international trade by expediting communication between enterprises and customers, simplifying the sharing of information, negotiating contracts, and tracking shipments. Additionally, it allows enterprises to broaden their client reach by utilizing e-commerce platforms, therefore diminishing trade obstacles and fostering worldwide economic integration. Therefore, ICT plays a crucial role in improving worldwide economic integration (Chung et al, 2013; Liu & Nath, 2013; Bensassi et al, 2015).

There are three ways in which this study stands apart from the rest of the literature. First, the study fills a theoretical gap for a complete view of technology and sustainable development in CAREC countries. This new theoretical and methodological approach studies the indirect effect (neither stated nor absent) in addition to the direct influence. This makes it possible to demonstrate that improving environmental standards and commerce is appropriate for tackling the major issues associated with sustainable development. This is one of the first studies to analyze the mediating role of environmental quality and trade in the ICT growth nexus in the CAREC countries. Second, this study proposes to use the appropriate and reliable econometric technique SEM, which sets it apart from the current literature from an empirical standpoint. Third, this study aims to shed light on the comprehensive proxies of technology to assess direct and indirect effects on sustainable development. The econometrics model also considers a different proxy of moderating variables, including the energy efficiency score from the data envelopment analysis, and examines the causal links between variables.

The remaining paper includes sections on literature review, data and methods, empirical results & discussion, and conclusion and policy recommendations.

2. Literature Review

2.1. ICT-Development Nexus

The technology-growth model of Solow (1956)—refined by Barro (1991); Mankiw and Romer (1991)—suggests technology drives economic success. The Grossman and Helpman (1991); Lucas Jr (1988); Romer (1993) growth model includes technology as an endogenous element, linking it to human capital and innovation. ICT has advanced significantly in recent decades, but empirical evidence of its impact on GDP growth is mixed. Three theories have been explored: ICT-induced economic development, which suggests access to information, skills, and markets makes economic players more productive; ICT growth drives economic growth, requiring better infrastructure; and feedback, which links technological and economic advancement. Technology does not affect

economic growth, according to the neutrality hypothesis (Maiti et al, 2020). Various studies have linked ICT to growth (Jayaprakash & Pillai, 2022).

ICT has been found to positively impact growth in developing economies—for instance, Kallal et al, (2021); Wang et al, (2023); Ximei et al, (2022)—particularly in low and lower-middle income nations (Jayaprakash & Pillai, 2022). The samples from the developed nations showed similar results (Adedoyin et al, 2020; Appiah-Otoo & Song, 2021; Latif et al, 2018). However, some research found a positive correlation in wealthy nations and a negative correlation in developing nations (Nguyen & Doytch, 2022). Niebel (2018) suggested that developed nations benefit more from ICT growth than developing and growing nations. Thus, the nexus data is inconclusive and needs further study. Most research on ICT and growth demonstrates that technology enhances economic performance, although some provide inconsistent results, suggesting little effect (Breitung et al, 2022). The relationship between ICT and growth is inconclusive, and further research is needed to understand indirect mechanisms influencing growth. ICT can either encourage or hinder growth through direct and indirect causes, such as encouraging complementary innovations (Skorupinska & Torrent-Sellens, 2017) and attracting investment and training locals (Awad & Albaity, 2022). We form the hypothesis using the above literature:

Hypothesis 1: There is a direct, positive and significant impact of ICT/technology on SD.

2.2. ICT-CO2 Nexus and CO2-Development Nexus

Since the late 21st century, computer-based ICT has transformed production, consumption, and management. Policymakers and researchers have emphasized ICT's environmental impact (Usman et al, 2021). ICT and CO_2 emissions are complex and include pros and cons. In the optimistic view, ICT has enhanced life, the economy, and the environment. Telecommuting and website sharing minimize greenhouse gas emissions and conserve natural resources (Hilty & Aebischer, 2015). ICTs have revolutionized shopping patterns, improving business performance, efficiency, cost, and sustainability (Stiglitz, 2021). ICT innovations also reduce CO_2 emissions. Danish (2019) research revealed that ICT decreased BRI CO_2 emissions in 59 nations from 1990 to 2016. Chien et al (2021) found that ICT significantly lowered CO_2 emissions at lower emission quantiles in the BRICS countries from 1995 to 2018. The effect was weakest at low quantiles and strongest at high. Sun and Kim (2021) demonstrated that ICT lowered carbon intensity in the Chinese provinces from 2000 to 2017 despite regional reliance. Growing research demonstrates that ICT can cut CO_2 emissions in developing economies such as BRI and BRICS (Jin et al, 2017).

Research shows that ICT is causing a faster environmental impact than AI and 5G networks. ICT negatively impacts economic growth and CO_2 emissions in Southeast Asian countries (Lee & Brahmasrene, 2014). ICT affects carbon emissions differently in industrialized and developing nations, with wealthier countries achieving optimal development stages for CO_2 reduction while emerging countries struggle. Studies show a link between CO_2 emissions and sustainable development, with some studies showing an increase in economic growth in countries like the United States, China, and Japan, which implement green technologies and environmental laws (Azam et al, 2016). However, others find a negative correlation, suggesting that CO_2 emissions can hinder economic growth without green technologies or environmental constraints (Dogan & Aslan, 2017). Gross domestic product increases CO_2 emissions. Production activities that boost GDP use coal or petroleum to emit CO_2. Fuel use rises with GDP. Caporale et al (2021) used fractional integration and cointegration to study China's real GDP and CO_2 logarithms. A long-term link between variables in cointegration research suggests government CO_2 emission mitigation during economic expansion. We form the hypothesis using the above literature:

Hypothesis 2: ICT mediates the role of environmental degradation and is a positive and significant impact of ICT/technology on SD.

2.3. ICT-Trade Nexus and Trade-Development Nexus

ICT-driven productivity, efficiency, and transparency increase corporate profits and growth (Pradhan et al, 2022; Salahuddin & Gow, 2016). However, their impact on trade is unclear. ICTs improve logistics and supply chains by lowering inventory and transportation costs (World Bank, 2016). Recent studies show that the Internet and fixed-line phones have boosted Asia–Pacific trade (Chung et al, 2013), business in 40 emerging nations (Liu & Nath, 2013), and increased commerce in 200 nations (Lin, 2015). Bensassi et al (2015) found that ICT capital stock increased Spanish exports from 2003 to 2007. In 2007 and 2010, broadband infrastructure increased EU regional commerce (Barbero & Rodriguez‐Crespo, 2018). From 1995 to 2008, Abeliansky and Hilbert (2017) and Rodriguez-Crespo et al (2021) discovered that affluent nations traded subscription quantity more than emerging countries traded quality. Rodríguez-Crespo and Martínez-Zarzoso (2019) found that Internet users and trade volume are income- and product-dependent.

Several studies examined commerce and economic growth. Yildirim et al (2012) found that trade volume improves the environment and the economy. Trade increases growth through technology transfer, comparative advantage, and massive economies. Wacziarg and Welch (2008) found trade liberalization boosts growth. Increasing the average trade ratio to GDP promoted economic growth in liberalized nations. Zafar et al (2015) examined trade openness and GDP in 158 countries across time. The study identified a long-term positive association between trade openness and GDP and suggested that global integration can increase prosperity. The study found a short-term negative link between trade openness and GDP. The study indicated that increased national wealth reverses this short-term effect. Keho (2017) found that trade openness boosts economic growth in the short and long term. Alam and Sumon (2020) showed that trade increased economic growth in 15 Asian economies. We form the hypothesis using the above literature:

Hypothesis 3: ICT mediates the role of trade and is a positive and significant impact of ICT/technology on SD.

2.4. Research Gap

The literature above provides a strong theoretical basis for this study of how ICT affects SD, but it has several limitations. First, ICT boosts economic growth in fast-emerging economies, sub-Saharan African states, developing economies, G-20 economies, and BRICS nations. In this connection, CAREC has not been studied extensively. Second, the proxy for ICT may impact the outcome. Most literature uses fixed broadband subscriptions, Internet users, and mobile phone users as ICT proxies. This study analyzes e-governance as a proxy of technology to see how it improves government service delivery, transparency, and citizen participation. The existing study on the impact of ICT on GDP, trade, and the environment needs to be more conclusive. Various literature establishes a connection between ICT and development, encompassing financial inclusion, ICT distribution, and economic growth (Chatterjee, 2020). Research has indicated a positive correlation in affluent countries and a negative correlation in undeveloped countries. In contrast to most studies examining the relationship between ICT and growth, specific investigations have yielded inconclusive findings, suggesting limited or negligible advantages (Breitung, 2021).

ICT can have a dual impact on environmental quality. Several experts claim that implementing economic growth plans will significantly impact environmental performance, as there is a strong

correlation between global CO_2 emissions and economic activity. Several research studies still need a credible one-way link of ICT with CO_2 emissions (Usman et al, 2021).

Furthermore, the influence of ICT on trade is a subject of ongoing debate. ICT has revolutionized international trade, foreign direct investment (FDI), and the accessibility of financial services to promote inclusive economic growth. ICT enhances electronic commerce, digital financial transactions, and online business platforms (Pradhan et al, 2014; Salahuddin & Gow, 2016; Shirazi, 2010). The effect of ICT on trade remains uncertain, as shown by certain specialists (Cardona et al, 2013).

Therefore, the influence of ICT on these three domains remains variable and lacks convergence. The researchers have provided multiple justifications for this inconsistency. Factors that need to be considered include the features of the dataset (whether it is cross country or panel data), the classification of the country as developed or developing, the methodological approach used, and the proxies used for measuring ICT. Most research has utilized fixed broadband subscribers, Internet users, and mobile phone users as proxies for measuring ICT usage.

This study employs the e-governance index and its subindices and telephone subscriptions to collect reliable evidence on the impact of ICT on GDP, trade, and the environment. The comprehensive measure will add to the existing body of knowledge, introducing new evidence by combining the traditional measure (telephone subscriptions) and new measures to help compare and contrast it with the existing literature.

Third, existing research examines how ICT affects economic development. Commerce and environmental quality trade and carbon emissions may mediate economic progress in the age of industrialization and globalization. However, no studies have examined these two mediating routes. This study also calculated energy efficiency scores using data envelopment analysis and examined the impact of ICT on GDP. Fourth, trade and ICT have analogous works. Most studies have examined national subscription statistics. Panel data can help track ICT progress.

3. Material and Methods

This study uses quantitative data from 2000 to 2022 on technology, trade, and SD in the CAREC region. The choice of time period is constrained by the availability of e-governance indices data—available only after the 2000s. Afghanistan is left out of the sample owing to a lack of available data. The CAREC region prioritizes five operational clusters: economic stability, trade and tourism, infrastructure, agriculture, and human development. The integration of ICT across these clusters enhances productivity and efficiency. China has grown exponentially in these clusters, outperforming other CAREC and global countries.

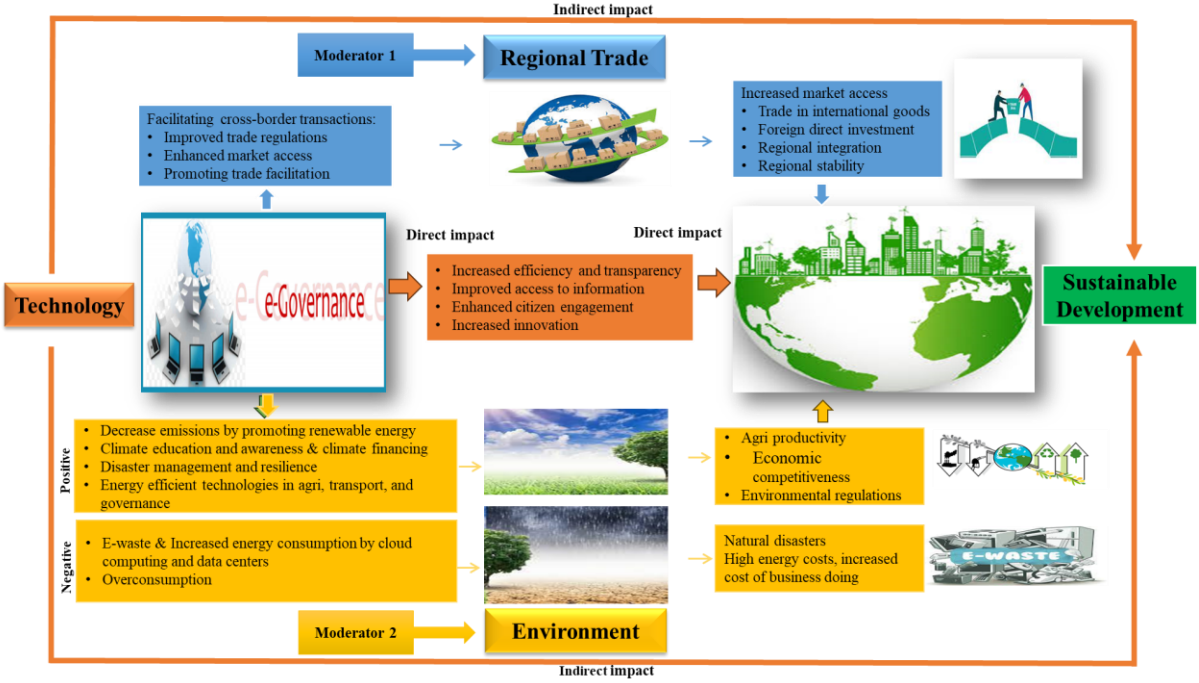
The main dependent variable is sustainable development, which is measured through GDP per capita. Sustainable economic development refers to the process of promoting economic growth while simultaneously safeguarding natural resources and the environment, with the aim of meeting the present and future requirements of humanity (Zhang et al, 2023). Moreover, technology is used as an independent variable. Technology has the potential to enhance productivity, efficiency, and innovation across various industries, leading to increased economic growth (Arvin et al, 2021; Odhiambo, 2022). E-government development index (egovi), e-participation index (epartiind), online service index (osind), teleinfrastructure index (teleinfind), and fixed telephone subscriber (ltelesub) are used as proxies for technological innovation in the current analysis. Trade and environmental quality are two mediating factors. ICT uptake boosts online trading, enhancing efficiency, productivity, and transparency (Abeliansky & Hilbert, 2017). These boost return on investment,

trade openness, and flows among economies—ultimately economic growth rises in the economy. Four proxies of trade—namely, export volume index (EXPVO), import volume index (IMPOV), exports percent of GDP (Exports) and imports percent of GDP (Imports) are used in the analysis.

To measure environmental quality, the second mediator, we use three proxies—energy consumption (EC), energy efficiency (EEF), and ecological footprint (EFP). Energy consumption serves as an indicator of environmental quality owing to its significant role in generating greenhouse gas emissions and air pollution, which directly influence climate change and air quality. Burning fossil fuels such as coal, oil, and natural gas emits greenhouse gases into the atmosphere, leading to the global warming. Minimizing energy usage is essential for addressing and alleviating the effects of climate change. An average American household consumes approximately 10,000 kWh of electricity annually. If every individual were to decrease their energy usage by 10 percent, they might conserve 1,000 kWh, which is sufficient to provide power to a typical residence for two months. Conserving energy not only decreases electricity expenses but also diminishes our carbon footprint and decelerates climate change (Vitality.io, 2022).

Technology can reduce CO2 emissions through improved decision-making, transportation infrastructure, and energy efficiency (Usman et al, 2021). However, ICT adoption has high environmental costs owing to increased CO2 emissions and increased energy demand, contributing to environmental degradation (Chien et al, 2021). Similarly, the relationship between CO2 emissions and economic growth is complex, with conflicting evidence. Some studies suggest that higher levels of CO2 emissions are associated with greater economic growth, as industries and businesses may rely heavily on fossil fuels for production (Shahbaz et al, 2016). However, Caporale et al (2021) found a negative relationship between CO2 emissions and economic growth. Along with the primary external factors, we have also taken into account several internal control variables, such as the capital stock (Capital), employed labor force, urban population (UP), gross fixed capital formation, FDI, natural resource rents (Rents), exchange rate (ER), government effectiveness (GovEff), industrial value added (IVA), number of patent (INNOV) that has been suggested by earlier studies as potential predictors of sustainable development, environmental quality, and trade. Figure 2 depicts the theoretical connection between ICT and sustainable development via trade and environment channels.

Figure 2: Model of the Study



Source: Author construction

The sources of data used in the analysis are provided in Table 1. The World Development Indicators (WDI), the United Nations (UN), Quality of Government (QoG) Institute, Gothenburg and Penn World Tables are the major sources of data for the study.

Table 1: Description of Variables

Variable	Role	Description	Source
GDP	Dependent	GDP per capita at constant US dollars	WDI
E-Government Development Index	Independent	It measures e-government development in States, considering infrastructure, education, online services, telecommunication connections, and human capability, aiming to improve access and inclusion.	UN
E-Participation Index		It is an e-government survey index that consists of three essential components: e-information, e-consultation, and e-decision-making.	
Online Service Index		It is a quantitative tool developed to evaluate each country's ease of access to features or services, and assigning 1 point if available and 0 points if not available	
TeleInfrastructure Index		It is an average of four indicators: Internet users, mobile subscribers, fixed telephone lines, wireless broadband subscribers.	
FTS		Fixed telephone subscriptions per 100 people	WDI
Export Volume and Import Volume Index	Mediator 1	UNCTAD's export/import volume indexes are the ratio of export/import value indexes to unit value indexes, based on consistent data from countries and projections using previous year's trade values as weights.	
Energy Consumption	Mediator 2	Energy use (kg of oil equivalent per capita)	
Controls in Mediator 1 Equation			

FDI	In GDP and Mediator 1 equation	Foreign direct investment, net inflows (% of GDP)	WDI
Rents	Mediator 1 equation	Total natural resources rents (% of GDP)	
Exchange Rate		Official exchange rate (LCU per USD, period average)	
Controls in Mediator 2 Equation			
Government Effectiveness	Mediator 2 equation	Government effectiveness measures public service quality, civil service independence, policy formulation and implementation, and government commitment credibility.	WDI
IVA		Industry (including construction), value added per worker (constant 2015 USD)	
INNOV		Log of total patent applications, residents and nonresidents	
Urban Population	In GDP and Mediator 2 equation	Log of total urban population	
Capital	In GDP equation	Gross fixed capital formation (% of GDP)	
Variables used for Robustness			
Capital Stock	For data envelopment analysis (DEA)	Log of capital stock at constant 2017 national prices (millions of USD)	Penn World Tables
Employed Labor Force		Log of number of persons engaged (millions)	
Energy Efficiency	Mediator 2	Total factor productivity change score extracted from DEA using capital stock, labor force, and energy consumption as inputs and GDP per capita as output.	Author Calculation
Ecological Foot Print	Mediator 2	Ecological footprint of consumption per person (gha per person)	Quality of Government Institute, Gothenburg
Exports	Mediator 1	% of GDP	WDI
Imports	Mediator 1		

Note: the study followed the measurement of variables adopted by earlier studies

Table 2 shows the summary of the statistics for the 230 observations of the variables that are used in the study. Table 2 highlights the nations and years with the highest and lowest values of the specified variables in accordance with the observations.

Table 2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
GDP	10.246	6.940	6.065	31.284
teleinfind	0.221	0.200	0.017	0.805
egovi	0.451	0.164	0.000	0.863
osindex	0.383	0.243	0.000	0.934
epartiind	0.307	0.281	0.000	0.964
ltelesub	2.274	0.607	0.474	3.558
EXPVO	5.253	0.612	4.186	6.688
IMPVO	5.579	0.621	4.435	6.729
Exports	22.949	2.135	19.578	28.910
Imports	23.070	1.928	19.962	28.630
EC	7.112	0.839	5.636	8.474
EEF	0.988	0.056	0.607	1.025
EFP	2.788	1.828	0.726	7.276
UP	14.562	3.770	3.671	20.599
IVA	23.372	2.318	20.613	29.462
Rents	13.221	13.678	0.451	75.366
ER	4.223	2.956	-0.243	9.310
FDI	432.720	1294.915	-37.173	5232.143
Capital	13.095	1.766	10.677	18.417
INNOV	6.373	2.758	0.693	14.249
GovEff	33.034	19.693	2.439	76.442

Source: Author calculation, Observations=230

Table 3 provides the correlation analysis. There is a negative relationship between SD and the technological proxies—namely egovi, epartiind, teleinfind, and 1telesub—except osind. In terms of trade, except for import volume index, all other proxies have a positive relationship with GDP. On the other hand, EC and EFP have a positive relation with GDP whereas EEF has a positive correlation with GDP.

Table 3: Correlation Analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1												
2	-0.15	1											
3	-0.24	0.84	1										
4	0.09	0.75	0.87	1									
5	-0.02	0.79	0.81	0.89	1								
6	-0.41	0.34	0.53	0.38	0.26	1							
7	0.03	0.56	0.60	0.62	0.54	0.57	1						
8	-0.26	0.66	0.76	0.68	0.66	0.52	0.69	1					
9	0.19	0.32	0.39	0.53	0.39	0.44	0.67	0.33	1				
10	0.26	0.34	0.41	0.58	0.42	0.37	0.62	0.40	0.95	1			
11	-0.32	0.27	0.36	0.21	0.22	0.60	0.37	0.23	0.44	0.25	1		
12	0.09	-0.08	-0.09	-0.01	-0.11	0.20	0.11	0.04	0.20	0.18	0.07	1	
13	-0.29	0.22	0.31	0.17	0.29	0.34	0.26	0.21	0.24	0.08	0.78	-0.12	1

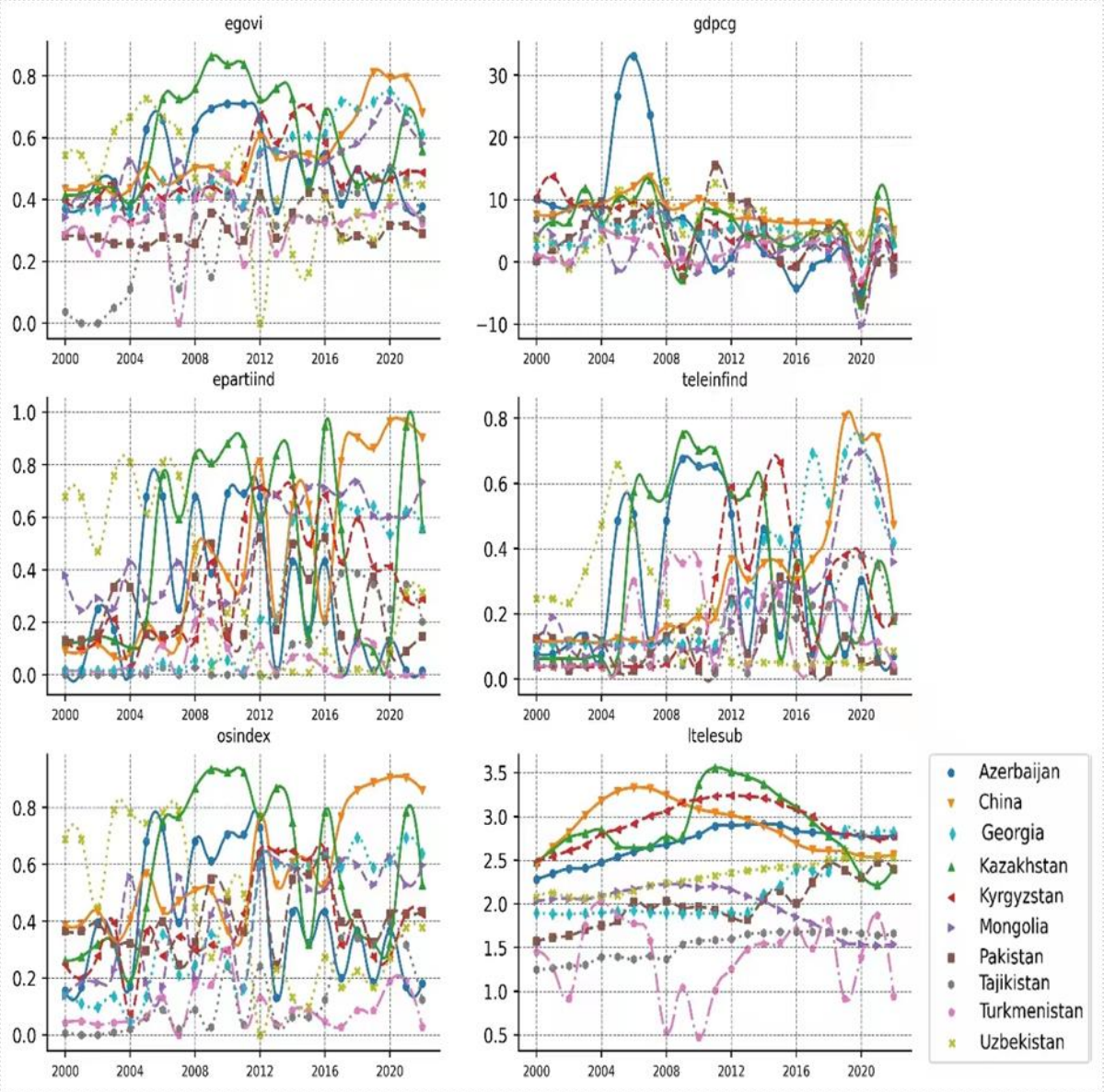
Note: 1=GDP, 2=teleinfind, 3=egovi, 4=osindex, 5=epartiind, 6=1tellesub, 7=EXPVO, 8=IMPVO, 9=mexp, 10=mimp, 11=EC, 12=EEF, 13=EFP

Source: Author calculation

3.1. Graphical Analysis

Figure 3 displays the graphical representation of five proxies of ICT and economic growth within the CAREC nations. The figure illustrates a pattern characterized by a combination of mixed, overlapping, and increasing trends throughout time. China and Kazakhstan exhibit the highest ICT trend, while Tajikistan demonstrates the lowest. Exports and imports throughout the CAREC economies are shown in Figure 4. The highest export (import) is found in China and Azerbaijan (Kazakhstan). During the aforementioned years, Tajikistan (Turkmenistan and Uzbekistan) also have the lowest export (import). Moreover, the economic growth trend is mixed in all the CAREC economies.

Figure 3: Graphical Analysis of ICT and Economic Growth in the CAREC Countries

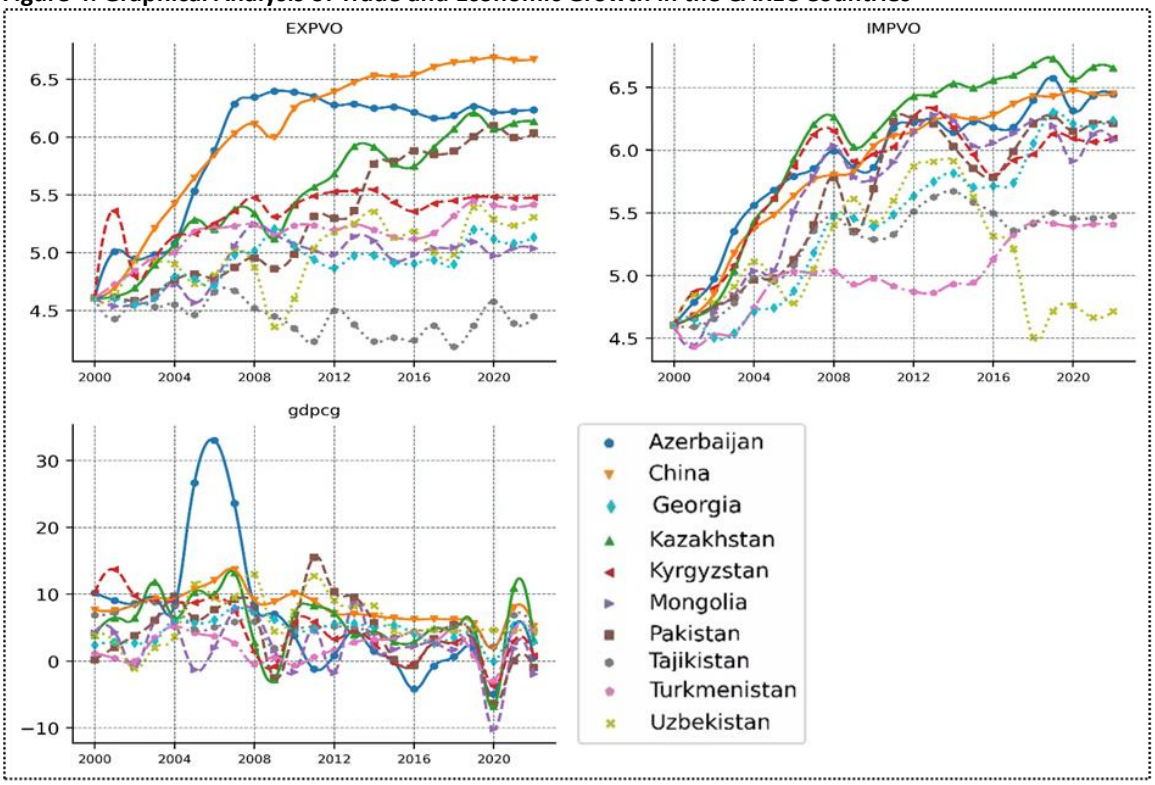


Source: Author construction

Figure 5 illustrates the presence of a mixed trend in proxies of environmental quality. In terms of EFP Pakistan has observed the greatest level of ecological footprint, whereas Turkmenistan has exhibited a relatively low tendency in this regard. In comparison to other countries, all the CAREC economies exhibit a similar level of energy efficiency (EEF). In terms of energy consumption, Kazakhstan and

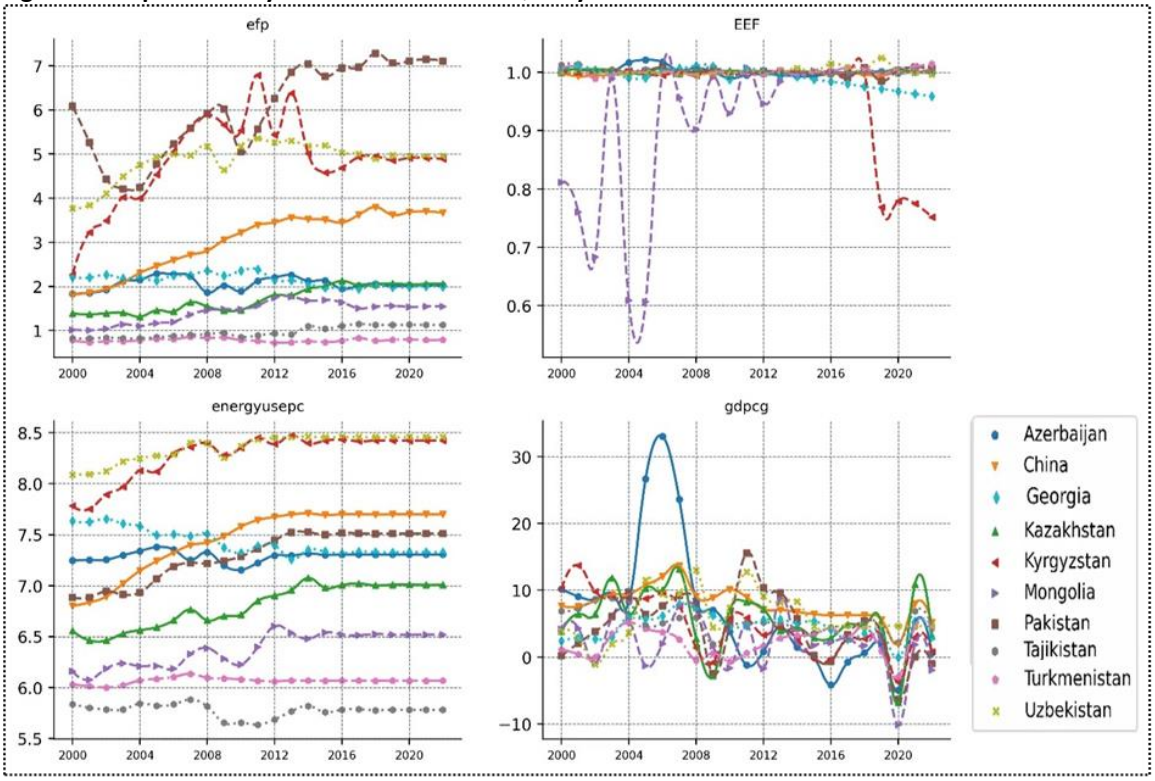
Uzbekistan (Tajikistan) have (has) higher (lower) trend of energy consumption among the CAREC economies.

Figure 4: Graphical Analysis of Trade and Economic Growth in the CAREC Countries



Source: Author construction

Figure 5: Graphical Analysis of Environmental Quality and Economic Growth in the CAREC Countries



Source: Author construction

3.2. Econometric Model and Methodology

Structural equation modeling (SEM) is a commonly employed statistical technique in the fields of business, psychology, and economics, as evidenced by its extensive utilization across many studies (Moyle et al, 2021). It is a tool for looking at the relationships and complex interrelationships between many different factors. It can measure each variable's pathway coefficient with great accuracy and test how the hidden, observation, and error variables are linked in the model. Latent variables cannot be seen directly, so they are measured using factors that can be seen (Jöreskog & Goldberger, 1975; Rabe-Hesketh et al, 2007). Also, the direct, indirect, and overall effects of exogenous factors on endogenous variables can be figured out. The benefits of using SEM and its structure are explained in Appendix A.

Sustainable development (GDP per capita), technological factors (teleinfind, egovi, osindex, epartiind, and 1telesub), trade (EXPVO, IMPVO) and environmental quality (EC) are regarded as manifest variables in structural equation modeling. Technology is one of them, and it has an exogenous effect on trade, environmental quality, and sustainable development. Trade and environmental quality are mediating factors that have a direct impact on SD. Technology, however, has an impact on trade, environmental quality, and GDP. Therefore, technological factors have an impact on trade and environmental quality, which in turn have an impact on GDP both directly and indirectly. Afterwards, the CAREC countries' growth levels are seen to be affected both directly and indirectly as:

$$GDP = f(\ ICT, Trade, Environment, UP, FDI, Capital) \quad (4)$$

$$Trade = f(\ ICT, ER, Rents, FDI) \quad (5)$$

$$Environment = f(\ ICT, IVA, INNOV, GovEff, UP) \quad (6)$$

Above relationship can be written in econometric form as:

$$GDP_{it} = \alpha_0 + \alpha_1 ICT_{it} + \alpha_2 EXPVO_{it} + \alpha_3 EC_{it} + \alpha_4 UP_{it} + \alpha_5 FDI_{it} + \alpha_1 Capital_{it} + \varepsilon_{it} \quad (7)$$

In Equation (7), we have used energy consumption as a proxy for environmental quality. For trade export volume index and for ICT five proxies of e-governance (egovi, epartiind, osindex, teleinfind, ltelesub) are used alternatively.

$$GDP_{it} = \alpha_0 + \alpha_1 ICT_{it} + \alpha_2 IMPVO_{it} + \alpha_3 EC_{it} + \alpha_4 UP_{it} + \alpha_5 FDI_{it} + \alpha_1 Capital_{it} + \varepsilon_{it} \quad (8)$$

in Equation (8), all else remaining the same, import volume index is used as a proxy for trade.

$$Trade_{it} = \beta_0 + \beta_1 ICT_{it} + \beta_2 ER_{it} + \beta_3 Rents_{it} + \beta_4 FDI_{it} + \varepsilon_{it} \quad (9)$$

$$Environment_{it} = \gamma_0 + \gamma_1 ICT_{it} + \gamma_2 IVA_{it} + \gamma_3 INNOV_{it} + \gamma_4 GovEff_{it} + \gamma_5 UP_{it} + \varepsilon_{it} \quad (10)$$

Since, trade and environment are also endogenous in our defined system, Equation (9) is used for trade equation and Equation (10) is used for environment equation. UP, FDI, and Capital are used as control in the GDP equation. FDI, ER, and Rents are used as control in the trade equation while IVA, INNOV, GovEff and UP are used as control in the environment equation.

Robustness Checks

a) By changing proxy of ICT

The study used five proxies of ICT to test the robustness of estimates and reported results in the baseline tables.

b) By changing proxy of trade

Exports and Imports as a percent of GDP are used in place of EXPVO and IMPVO for robustness.

c) By changing proxy of enviroment

Ecological footprint and energy efficiency score estimates from data envelopment analysis is used for robustness of environment proxy.

d) By changing measurement algorithum

Instead of maximum likelihood, asympototic distribution free (ADF) is used as an other robustness measure. ADF is a GMM-based method and also controls for any endogeniety issues in the data.

4. Results and Discussion

The findings from the SEM, which used trade and environmental quality as mediating variables to examine the direct and indirect effects of technology on EG, are presented in this section.

4.1. ICT-Development via Export Volume and Energy Consumption

Table 4 demonstrates that the model is well-fitting, the variables and their relationships can be fairly explained, and the exogenous and endogenous variable settings are reasonable. Table 4 indicates the SEM estimates obtained by using five proxies of ICT—namely, teleinfind, egovi, osindex, eparti, and 1telesub. Results indicated that the direct impact of ICT indicators is negative on GDP, whereas a positive impact is found in the case of 1telesub. In terms of trade, ICT has a positive impact on export volume index (EXPVO). The findings are aligned with Abeliansky and Hilbert (2017); Rodriguez-Crespo et al (2021). The impact of EXPVO on GDP is positive and significant, indicating that exports improve GDP in the CAREC economies. This finding is consistent with Alam and Sumon (2020); Keho (2017), and Wacziarg and Welch (2008). All indicators of ICT (exogenous variable) have a positive impact on EC (endogenous variable). These findings align with Monzon et al (2017); Razzaq et al (2021), and Salahuddin et al (2016).

Table 4: SEM Estimates ICT-Development with EXPVO and EC

Exogenous Variable	Path	Endogenous Variable	teleinfind	egovi	osindex	eparti	1telesub
ICT	→	EC	1.010***	2.613***	1.436***	0.855***	0.633***
			(0.268)	(0.325)	(0.216)	(0.165)	(0.088)
			(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
EC	→	GDP	0.964***	0.946***	0.961***	1.008***	0.877***
			-0.077	(0.082)	(0.083)	(0.078)	(0.082)
EXPVO	→	GDP	0.607***	0.478***	0.501***	0.589***	0.401***
			-0.097	(0.099)	(0.097)	(0.092)	(0.094)
ICT	→	GDP	-0.747***	0.026	-0.130	-0.60***	0.233**
			-0.263	(0.381)	(0.260)	(0.186)	(0.109)
ICT	→	EXPVO	1.806***	2.655***	1.909***	1.519***	0.653***
			-0.166	(0.200)	(0.123)	(0.112)	(0.063)
Observations							
Var(e.EC)			0.319***	0.260***	0.281***	0.301***	0.273***
			-0.032	(0.026)	(0.028)	(0.030)	(0.027)
Var(e.GDP)			0.386***	0.401***	0.401***	0.381***	0.381***
			-0.038	(0.040)	(0.040)	(0.038)	(0.038)
Var(e.EXPVO)			0.222***	0.189***	0.161***	0.186***	0.231***
			-0.022	(0.019)	(0.016)	(0.018)	(0.023)
Chi2(Model vs Saturated)			738***	646.9***	643***	706.2***	706.1***
R2 GDP			0.99	0.99	0.99	0.99	0.99
R2 EC			0.45	0.52	0.52	0.48	0.53
R2 Trade			0.44	0.55	0.59	0.53	0.42
R2 Overall			0.99	0.99	0.99	0.99	0.99

Note: *** indicates significance is less than 0.01, "→" indicates path points between variables, Chi2 is chi2 statistics, under the premise of significance, the smaller the better. UP, IVA, INNOV, GOVEFF are used as control in EC equation, UP, FDI, Capital in GDP equation and FDI, ER, Rents in EXPVO equation.
Source: Author calculation

Figures 6 to 10 show that the direct impact of ICT indicators is negative on GDP except in the case of a fixed telephone subscription. However, the indirect impact of ICT is positive and significant on GDP through export volume index and energy consumption. Table 5 summarizes the direct, indirect, and total impact of ICT on growth through EC and EXPVO. The total impact is positive and significant in all proxies of ICT. EXPVO that changes GDP have standardized path coefficients of 0.607, 0.478, 0.501, 0.589, and 0.401 in the model of the tele infrastructure index, e-governance index, online service index, e-participation index, and fixed telephone subscription, respectively. The impact is substantial, and it is going in the positive direction. EC that changes GDP have standardized path coefficients of 0.964, 0.964, 0.961, 1.008, and 0.877 in all proxies of ICT, respectively.

The impact is substantial and going in a positive direction. It supports our hypothesis that technology increases GDP through energy consumption and export volume and supports earlier findings (Mayer et al, 2020; Nair et al, 2020; Pradhan et al, 2020). The total impact of ICT is positive in all dimensions of ICT. The parameter estimates for the structure equation that shows how ICT affects GDP are given in Table 5.

Figure 6

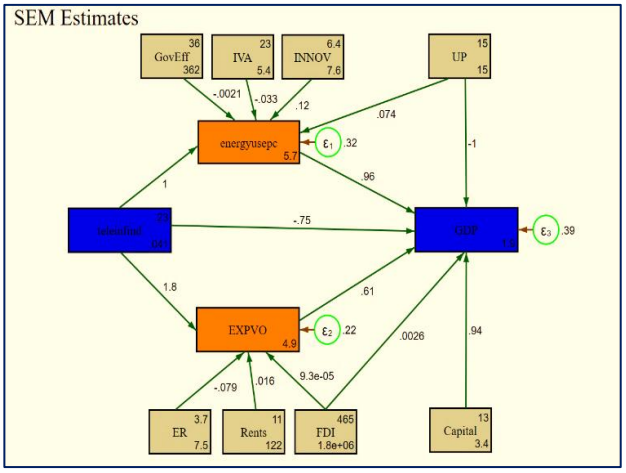


Figure 7

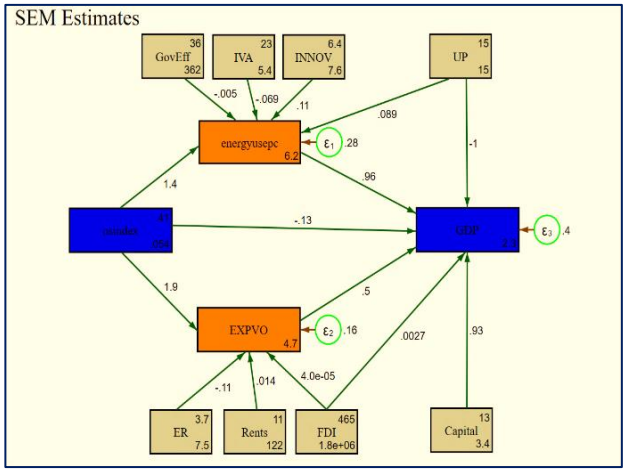


Figure 8

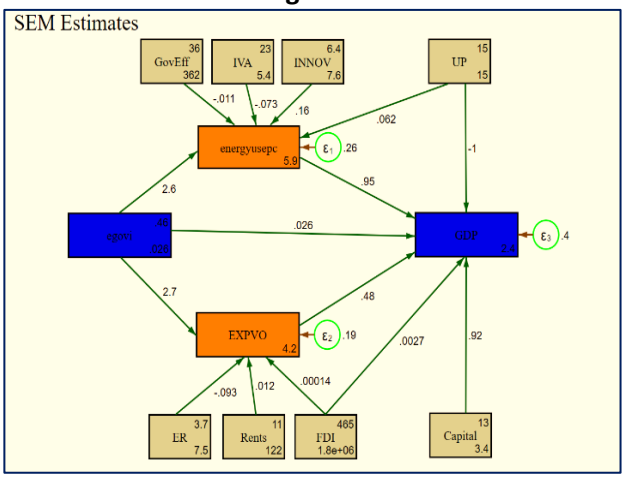


Figure 9

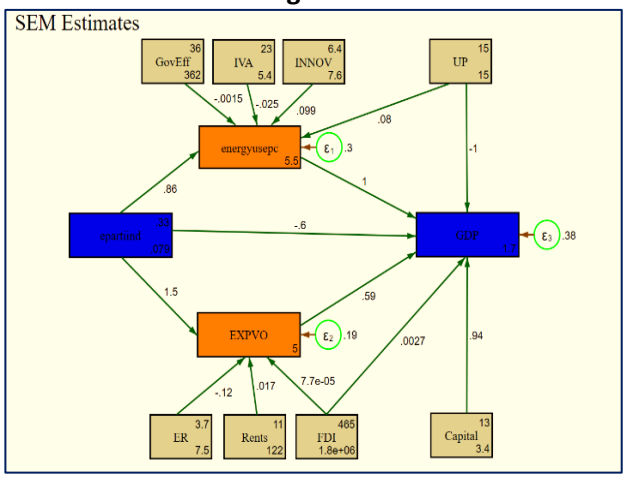
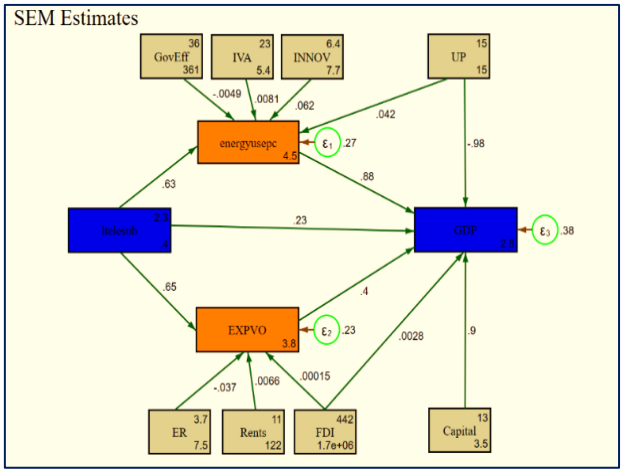


Figure 10



Source: Author constructions

Table 5: Direct, Indirect, and Total Effects from ICT to GDP through EC and Exports

Exogenous Variable	Endogenous Variable	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
	GDP	-0.747**	2.082***	1.335***
ICT	EC	1.021***	-	1.021***
	EXPVO	1.806***	-	1.806***
EC	GDP	0.964***	-	0.964***
EXPVO	GDP	0.607***	-	0.607***
E-Governance Index				
ICT	GDP	0.0263	4.001***	4.027***
ICT	EC	2.889***	-	2.889***
ICT	EXPVO	2.655***	-	2.655***
EC	GDP	0.946***	-	0.964***
EXPVO	GDP	0.478***	-	0.478***
Online Service Index				
ICT	GDP	-0.130	2.023***	1.893***
ICT	EC	1.109***	-	1.109***
ICT	EXPVO	1.909***	-	1.909***
EC	GDP	0.961***	-	0.961***
EXPVO	GDP	0.501***	-	0.501***
E-Participation Index				
ICT	GDP	-0.604**	1.662***	1.058***
ICT	EC	0.762***	-	0.762***
ICT	EXPVO	1.519***	-	1.519***
EC	GDP	1.008***	-	1.008***
EXPVO	GDP	0.589***	-	0.589***
Fixed Telephone Subscriptions				
ICT	GDP	0.233*	0.919***	1.152***
ICT	EC	0.749***	-	0.749***
ICT	EXPVO	0.653***	-	0.653***
EC	GDP	0.877***	-	0.877***
EXPVO	GDP	0.401***	-	0.401***

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculations

4.2. ICT-Development via Import Volume and Energy Consumption

Table 6 considers energy consumption and second proxy of trade—namely, import value index—as mediating variables to check the impact of ICT on GDP. The path coefficients of ICT affecting GDP are 3.661 (egovi), 2.053 (osindex), and 1.141 (1telesub). The impact is significant and the trend is positive with two proxies of ICT. The path coefficients of ICT affecting IMPVO and EC are significant with positive direction. These two mediating variables have a positive influence on GDP. In short, ICT influences GDP positively, directly and indirectly.

Table 6: SEM Estimates ICT-Development with IMPVO and EC

Exogenous Variable	Path	Endogenous Variable	teleinfind	egovi	osindex	eparti	1telesub
ICT	→	EC	0.208	0.575**	0.009	0.117	0.143**
			(0.182)	(0.240)	(0.154)	(0.115)	(0.059)
EC	→	GDP	0.802***	0.734***	0.528***	0.767***	1.083***
			(0.206)	(0.189)	(0.203)	(0.213)	(0.171)
IMPVO	→	GDP	0.648***	0.009	0.071	0.642***	0.405***
			(0.174)	(0.172)	(0.188)	(0.186)	(0.119)
ICT	→	GDP	0.347	3.661***	2.053***	0.229	1.141***
			(0.449)	(0.589)	(0.419)	(0.326)	(0.118)
ICT	→	IMPVO	2.035***	2.942***	1.937***	1.616***	0.501***
			(0.146)	(0.169)	(0.114)	(0.100)	(0.067)
Observations							
Var(e.EC)			0.147***	0.144***	0.148***	0.147***	0.143***
			(0.015)	(0.014)	(0.015)	(0.015)	(0.014)
Var(e.GDP)			0.841***	0.710***	0.755***	0.842***	0.568***
			(0.083)	(0.070)	(0.075)	(0.083)	(0.056)
Var(e.IMPVO)			0.171***	0.135***	0.139***	0.148***	0.264***
			(0.017)	(0.013)	(0.014)	(0.015)	(0.026)
Chi2(Model vs Saturated)			838***	777.9***	898***	843.56***	782.1***
R2 GDP			0.98	0.98	0.98	0.98	0.98
R2 EC			0.25	0.27	0.25	0.25	0.28
R2 Trade			0.55	0.64	0.63	0.61	0.31
R2 Overall			0.99	0.99	0.99	0.99	0.99

Note: see note to Table 4
Source: Author calculations

Figures 11-15 show that the standardized path coefficients of the ICT affect on SD are 1.315 (e-governance) and 0.477 (fixed telephone subscriptions). This means that the effect is significant and the direction is up with two mentioned proxies of ICT. It means that the development of ICT is one of the things that affects the growth of the CAREC economies. The path coefficients of ICT, which affect the IMPVO and EC, are positive and significant. EC has a positive and significant impact on GDP with all proxies of ICT. However, the IMPVO influence on GDP is insignificant with all proxies of ICT. The parameter estimation of the structural equation of the impact of ICT on GDP is shown in Table 7.

In Tables 5 and 6, out of 10 estimated coefficients in seven cases the direct impact of ICT proxies is negative on GDP and in three cases the impact is positive (only when we use import volume as a proxy of trade). ICT has the potential to increase GDP by improving efficiency and promoting new ideas. However, it can also have adverse consequences such as expenses related to investment, displacement of jobs, mismatches in skills, worries over cybersecurity, unequal availability, and difficulties in allocating resources. Greater dependence on ICT can lead to cybersecurity vulnerabilities, financial setbacks, and diminished customer confidence. Ensuring a harmonious integration of economic expansion, energy efficiency, and sustainable practices is vital for sustainable long-term development while safeguarding the wellbeing of future generations.

Figure 11

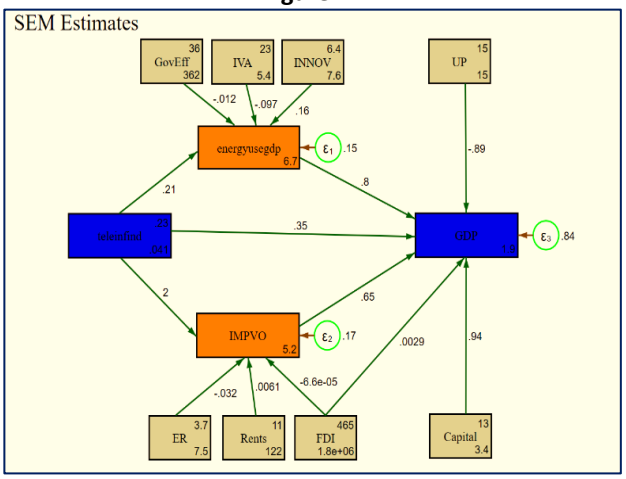


Figure 12

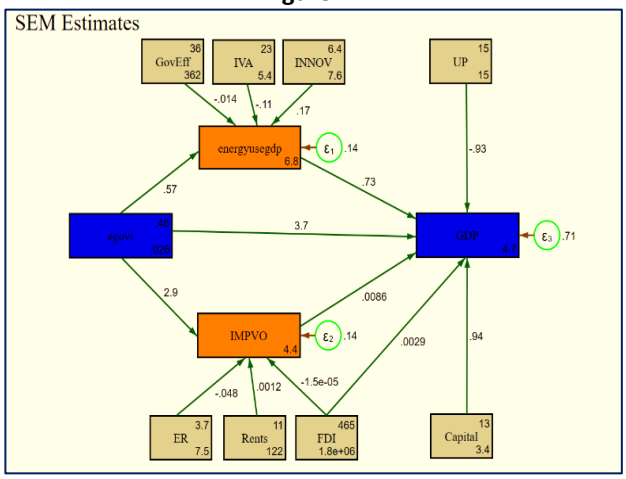


Figure 13

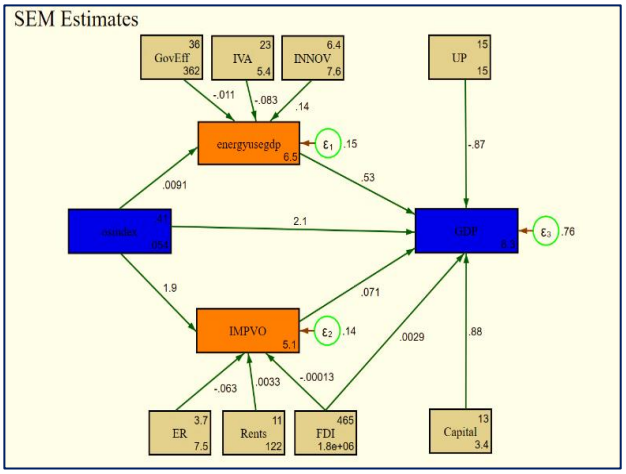


Figure 14

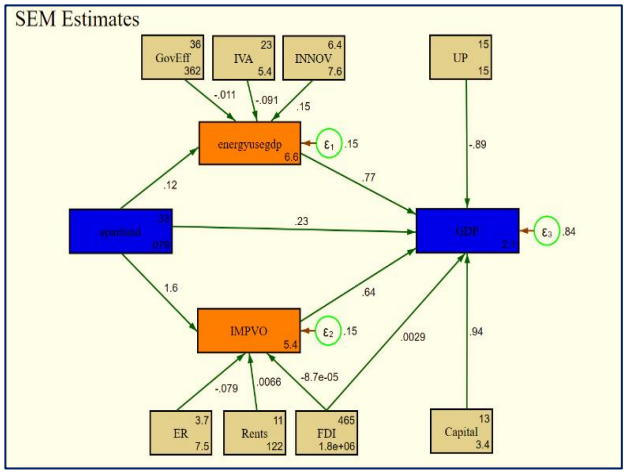
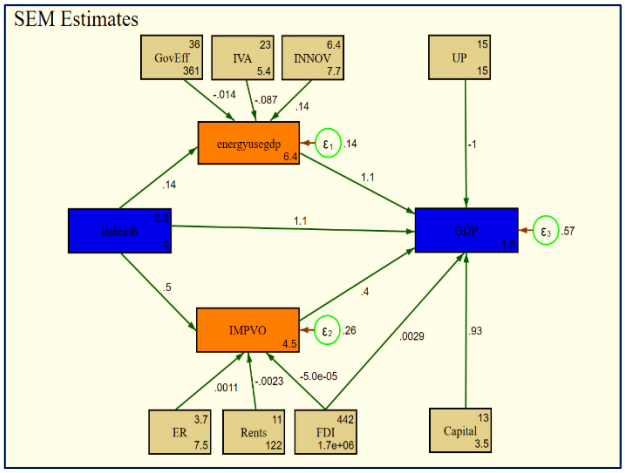


Figure 15



Source: Author construction

Table 7: Direct, Indirect, and Total Effects from ICT to GDP through IMPVO and EC

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.218	1.384***	1.166**
ICT	EC	1.021***	-	1.021***
ICT	IMPVO	2.035***	-	2.035***
EC	GDP	1.118***	-	1.118***
IMPVO	GDP	0.119	-	0.119
E-Governance Index				
ICT	GDP	1.315**	2.514***	3.830***
ICT	EC	2.889***	-	2.889***
ICT	IMPVO	2.942***	-	2.942***
EC	GDP	1.023***	-	1.023***
IMPVO	GDP	-0.150	-	-0.150
Online Service Index				
ICT	GDP	0.556	1.053**	1.609***
ICT	EC	1.109***	-	1.109***
ICT	IMPVO	1.937***	-	1.937***
EC	GDP	1.052***	-	1.052***
IMPVO	GDP	-0.0586	-	-0.0586
E-Participation Index				
ICT	GDP	-0.438	1.192***	0.755**
ICT	EC	0.762***	-	0.762***
ICT	IMPVO	1.616***	-	1.616***
EC	GDP	1.154***	-	1.154***
IMPVO	GDP	0.194	-	**0.194**
Fixed Telephone Subscriptions				
ICT	GDP	0.444***	0.692***	1.136***
ICT	EC	0.749***		0.749***
ICT	IMPVO	0.501***		0.501***
EC	GDP	0.953***		0.953***
IMPVO	GDP	-0.0442		-0.0442

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculations

4.3. Robustness Check

Next, we used the alternative proxies of trade and environment, changed the algorithm to ADF, and reported the results as a supplementary file. The results obtained after the indicated changes are robust and endorse our key findings. Table 7 indicates that the direct effect of ICT measures on GDP is negative, while the indirect effect of ICT is positive and substantial. However, when the import variable is utilized, it has a direct and indirect positive impact on GDP through ICT.

Table 8: Summary of Robustness Checks

ICT-Development via Export Volume and Energy Efficiency				
Exogenous Variable	**Endogenous Variable**	**Direct Effects**	**Indirect Effects**	**Total Effects**
teleinfind	GDP	-0.507	1.869***	1.362***
egovi	GDP	1.401**	1.901***	3.302***
osindex	GDP	0.898**	1.422***	2.320***
epartiind	GDP	-0.0357	1.435***	1.399***
ltelesub	GDP	0.703***	0.343***	1.045***
ICT-Development via Export Volume and Ecological Footprint				
teleinfind	GDP	-0.543	1.870***	1.327***
egovi	GDP	0.985*	2.479***	3.464***
osindex	GDP	0.616	1.631***	2.247***
epartiind	GDP	-0.403	1.770***	1.366***
ltelesub	GDP	0.644***	0.644***	0.644***
ICT-Development via Export Volume and Energy Consumption				
teleinfind	GDP	-0.547**	3.118***	2.571***
egovi	GDP	-0.232	5.717***	5.485***
osindex	GDP	-0.303	4.144***	3.841***
epartiind	GDP	-0.504***	2.778***	2.274***
ltelesub	GDP	0.222**	1.630***	1.852***
ICT-Development via Import Volume and Energy Efficiency				
teleinfind	GDP	0.446	0.598	1.044**
egovi	GDP	4.033***	-1.162*	2.871***
osindex	GDP	2.431***	-0.499	1.932***
epartiind	GDP	0.593	0.332	0.924***
ltelesub	GDP	1.060***	-0.0568	1.003***
ICT-Development via Import Volume and Ecological Footprint				
teleinfind	GDP	0.272	0.782*	1.054**
egovi	GDP	3.096***	0.0146	3.111***
osindex	GDP	1.862***	0.0128	1.875***
epartiind	GDP	-0.116	1.066***	0.950***
ltelesub	GDP	0.943***	0.0731	1.016***
ICT-Development via Import Volume and Energy Consumption				
teleinfind	GDP	-0.942***	3.355***	2.413***
egovi	GDP	-1.138**	7.043***	5.905***
osindex	GDP	-0.794**	4.429***	3.636***
epartiind	GDP	-0.822***	2.908***	2.086***
ltelesub	GDP	0.174	1.594***	1.768***

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculations

4.4. Discussion

This study aims to examine the direct and indirect impact of ICT in shaping GDP. Total impact of ICT is positive in all dimensions of ICT. ICT might boost economic growth by enhancing productivity, efficiency, and consumption through improving access to resources, information, and markets (Arvin et al, 2021). For example, most developing economies like Singapore, South Korea, and Taiwan seem

to have surpassed many advanced economies in terms of economic growth owing to the faster spread of ICT.

In terms of trade, ICT has a positive impact on export volume index. The justification for this finding is that ICT penetration increases economic activity, notably online trading activities including online marketing, e-commerce, digital financial transactions, and online company platforms. ICT improves efficiency, productivity, and transparency, boosting firms' return on investment. All these results increase trade openness and international trade flows. The results are consistent with the studies conducted by Abeliansky and Hilbert (2017); Rodriguez-Crespo et al (2021). The impact of exports on GDP is positive and significant, indicating that exports improve GDP in the CAREC economies. This finding is consistent with Alam and Sumon (2020); Keho (2017). The positive impact of trade on GDP can be described in three ways. First, foreign trade multipliers with trade openness can boost economic growth. Second, more exports could help countries get the foreign currency they need to trade on international markets and buy the resources they need to make money. Third, when exports grow, countries may be able to get a bigger part of the market. This can help them take advantage of economies of scale and reduce the risks of being exposed to currency fluctuations and other changes in the market.

Every ICT measure has a favorable effect on energy consumption. The swift advancement of technology and utilization of ICT is leading to increased energy usage in the region. For example, the energy demand in the CAREC countries reached 204 million tons of oil equivalent in 2020 and is expected to increase to a range of 254-290 million tons by 2030. Electricity is a significant contributor to overall energy consumption, although the use of natural gas is projected to increase because of its prevalent use in power generation, as well as in residential and industrial sectors (ADB, 2023). These results are consistent with those of Monzon et al (2017); Razzaq et al (2021), and Salahuddin et al (2016). Additionally, greater ICT usage might increase production, leading to higher energy demand and energy consumption. Informatization increases demand for ICT products and services, leading to increased electricity consumption (Bahmani-Oskooee et al, 2020). Further, EC increases the GDP. We reveal that the effect of energy consumption on economic growth has been significantly positive, suggesting that increasing energy consumption can boost economy. The relationship between energy consumption and GDP is strongly correlated, primarily driven by industrial production, infrastructure development, technical breakthroughs, standard of life, and worldwide trade. Industrial output, infrastructure expansion, and technology breakthroughs necessitate energy for diverse operations, hence fostering GDP and augmenting GDP. As nations progress and enhance their quality of life, there is a corresponding rise in the need for energy. Moreover, countries engaged in global trade indirectly contribute to the escalation of energy consumption. Findings are consistent with Li et al (2011) and Tang and Tan (2014), as energy consumption drives GDP. The utilization of ICT (ICT) in the CAREC region has been found to have a detrimental effect on energy efficiency. This, in turn, harms the GDP, which indicates that the current state of ICT in the CAREC region is not energy efficient. Consequently, if these countries attempt to improve energy efficiency, they may face challenges achieving their GDP targets. However, with the presence of import variable direct and indirect impact of ICT on GDP is positive. ICT can enhance supply chain management efficiency and cost-effectiveness, boosting trade and SD (direct impact). Moreover, by increasing productivity, innovation, and global connectivity and trade, ICT boosts SD in the presence of imports (indirect impact).

ICT has a positive and significant impact on ecological footprint. The energy demand and consumption in the CAREC countries are increasing rapidly owing to ambitious growth plans and technological improvements. Fossil fuel-generated electricity significantly contributes to the overall energy consumption of the region. Presently, wind and solar energy sources constitute a mere 6 percent of the total installed capacity in the region. Resource extraction processes in these countries

likewise rely heavily on antiquated and non-renewable energy sources. Hence, the amalgamation of increased energy consumption and substantial dependence on non-renewable energy sources results in an augmented ecological footprint (ADB, 2023). ICT development raises the ecological footprint of developing countries. Huang et al (2022) reveal that ICT improvements are far from reducing ecological footprints, implying environmental degradation. Because compensating and rebound effects are more likely in poorer nations, we suggest that ICT development may not be a viable ecological solution (Alataş, 2021). This finding matches (Lee & Brahmasrene, 2014) for ASEAN, (Raheem et al, 2020) for G-7 states, and (Avom et al, 2020) for 21 SSA nations. The positive impact of the ecological footprint on GDP could be because CAREC economies are in the early stages of GDP; the industry support system and public service are not perfect. Local governments chose energy-intensive, polluting companies to boost GDP under emission reduction pressure (Li et al, 2022).

5. Conclusion

Technology affects all nations, and as the world digitizes, it may grow more prevalent. The impact of technology is felt worldwide. There is little widespread study on how digital technology affects trade and the environment. This research adds to the corpus of work by analyzing the consequences of a wide range of digital technologies on EG through trade and environmental channels. Trade and environmental quality influenced the direct and indirect effects of ICT on EG in this study. The structural equation approach was used to examine the relationship between ICT, trade, environmental quality, and GDP in CAREC economies from 2000 to 2022. Overall, total impact of ICT on GDP is found positive and significant with all proxies of ICT. ICT has a positive impact on trade, EC, and EFP, but a negative impact on EEF. In return, trade, EC, and EFP have a positive impact on GDP and the influence of EEF is negative on GDP. ICT in the CAREC region is still not energy efficent and if these countries try to enhance EEF, they lose on GDP targets.

The study suggests that CAREC officials should collaborate on developing trade, environment, and ICT policies to promote EG. Uncoordinated trade policies and environmental degradation can harm the economy. To align trade liberalization and environmental quality with digitization and GDP plans, governments should prioritize boosting ICT broadcasting. This will strengthen supply chains, boost cross-border e-commerce trade, and improve digital governance systems. A strong ICT infrastructure can also lead to a more effective implementation of free and fair-trade practices among stakeholders. Thus, a well-designed ICT development plan can boost CAREC trade, environmental quality, and GDP.

The excessive use of ICT in selected economies can negatively impact the environment. To make the environment eco-friendly, economies should promote smart ICT products that increase energy efficiency. Governments should reduce reliance on non-renewable sources and develop cleaner, greener alternatives. ICT alone cannot cut pollution without cleaner energy usage. CAREC economies can enhance their industrial structure and boost efficiency with ICT. Prioritizing ICT adoption and investing in R&D can promote inclusive development and create environmentally friendly ICT products. Furthermore, digital governance systems can enforce these policies transparently. Policymakers should also address environmental degradation by prioritizing policies that incentivize the production and usage of environmentally friendly energy sources and green technologies. These measures aim to mitigate degradation and foster GDP by promoting the adoption of green technologies and environmentally friendly energy sources.

Trade openness and ICT-related factors significantly impact GDP. CAREC countries should implement rule-based policies for free and fair trade to increase trust and harmonize commerce. Exports have a significant positive impact on the region's EG, but the impact of imports is either negative or insignificant. The region, therefore, must adopt an export promotion strategy.

Countries with high ICT penetration—such as Kazakhstan, China, and Uzbekistan—must adopt green ICT to achieve economic and environmental sustainability that can be achieved by promoting renewable energy sources, such as solar panels or wind turbines, and developing energy-efficient technologies. On the other hand, countries lagging in ICT infrastructure—such as Pakistan, Turkmenistan, and Tajikistan—first need to invest more in energy-efficient ICT infrastructure and promote trade facilitation to realize their full potential. By harnessing the power of ICT through direct and indirect channels, these countries can overcome their current limitations and pave the way for sustainable development in the future.

As with other research studies, this study has limitations. However, it has expanded the understanding of the advantages and obstacles associated with ICT in the CAREC countries. First, the study was limited to 10 CAREC economies because the data for Afghanistan was missing. Second, additionally, it is important to note that, while the current analysis offers a comprehensive perspective on the CAREC economies, it is crucial to recognize that each country exhibits varying levels of ICT and EG. To adopt more focused strategies, it is imperative to conduct studies at provincial and national levels. Additionally, the inclusion of industry or district level data may provide further clarification. Future research may explore the nexus at subnational level for deeper insights as well as looking for some other mediation channels such as education and innovations.

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Appendices

Table A: Detailed Values of Figure 1

CAREC Countries	teleinfind	egovi	osindex	epartiind	1telesub
Azerbaijan	0.677	0.694	0.612	0.645	0.384
China	0.805	0.812	0.888	0.865	0.864
Georgia	0.740	0.750	0.611	0.767	0.534
Kazakhstan	0.752	0.863	0.934	0.874	0.807
Kyrgyz Republic	0.664	0.698	0.618	0.634	0.500
Mongolia	0.697	0.721	0.626	0.628	0.602
Pakistan	0.312	0.424	0.566	0.349	0.364
Tajikistan	0.377	0.504	0.397	0.382	0.25
Turkmenistan	0.355	0.481	0.298	0.318	0.102
Uzbekistan	0.657	0.727	0.744	0.687	0.613

Source: Author calculations

Appendix A: SEM

Using first-generation multivariate data analysis methods like multiple regression, logistic regression, and analysis of variance, researchers evaluate predicted correlations between variables. Other methods include logistic and multivariate regression. Many scientists from different areas have used these methods to find things that have changed the way we think about the world. There are three primary limitations associated with these approaches. These encompass the assumption of a simplistic model structure, the necessity for all variables to be considered observable, and the presumption that all variables are accurately assessed (Haenlein & Kaplan, 2004).

In a fundamental model framework, multiple regression analysis and its extensions operate under the assumption that there is a single layer of dependent and independent variables. This presents a notable limitation. As a result, basic models lack the ability to effectively estimate causal chains that propose a sequential relationship of 'A leads to B leads to C' or intricate nomological networks including several intervening variables. The reason for this is that causal chains can be approximated only under conditions of relative tranquility. Hence, the precision of the findings could be somewhat influenced by the very straightforward computations executed using the comparatively uncomplicated framework (Sarstedt, Hair Jr, Nitzl, Ringle, & Howard, 2020).

Second, two instances of observable data that can be incorporated into regression analysis (in units of money) are sales and age. Theoretical ideas, which are described as 'abstract, unobservable properties or attributes of a social unit or entity,' must be independently validated using confirmatory factor analysis (CFA) before being taken into consideration. As a result, there are problems in applying theoretical frameworks in the past (Bagozzi & Phillips, 1982).

Third, any observation made in the real world has the potential to contain random or systematic error. There are two classifications that apply to this error. Only when there is no possibility of systematic or random error in the measured variables should first-generation approaches be utilized. When assessing the relationships between the several measurements of theoretical concepts, this circumstance only sometimes occurs. The social sciences are one of the many scientific fields that regularly study abstract concepts like perception, attitude, and intention. These and many other fields of scientific research have been hampered by the inadequacies of first-generation methodologies.

To get around these problems, academics are turning more and more to second-generation methods. Researchers can model and estimate complex relationships between multiple dependent and independent variables using these methods, which are called structural equation modeling (SEM). Most of the time, ideas that are being thought about can be judged only informally because they are abstract. When estimating relationships, SEM takes into account possible errors in the measured variables. This means that the method gives a more accurate evaluation of the scientific ideas being looked at (Cole & Preacher, 2014).

Structural equation modeling (SEM) is a commonly employed statistical technique in the fields of business, psychology, and economics, as evidenced by its extensive utilization across many studies (Moyle, Carmignani, Moyle, & Anwar, 2021). It is a tool for looking at the relationships and complex interrelationships between many different factors. It can measure each variable's pathway coefficient with great accuracy and test how the hidden, observation, and error variables are linked in the model. Latent variables can't be seen directly, so they have to be measured using factors that can be seen (Jöreskog & Goldberger, 1975; Rabe-Hesketh, Skrondal, & Zheng, 2007). Also, the direct, indirect, and overall effects of exogenous factors on endogenous variables can be figured out. Equation (1) shows a standard SEM with variables that come from the outside and variables that come from the inside.

SEM is often used in business, psychology, and economics (Moyle et al, 2021). It is a tool for looking at the relationships and complex interrelationships between many different factors. It can measure each variable's pathway coefficient with great accuracy and test how the hidden, observation, and error variables are linked in the model. Latent variables cannot be seen directly, so they have to be measured using factors that can be seen (Jöreskog & Goldberger, 1975; Rabe-Hesketh et al, 2007). Also, the direct, indirect, and overall effects of exogenous factors on endogenous variables can be figured out. Equation (1) shows a standard SEM with variables that come from the outside and variables that come from the inside.

$$\eta = B\eta + \Gamma\xi + \zeta \quad (1)$$

In the structural equation, η represents endogenous variables, ξ represents exogenous variables, B represents endogenous variable coefficients, and ζ represents the residual.

Appendix B: Data Envelopment Analysis

The efficiency of a government or private entity determines its success. Assessing the efficiency of similar units can uncover and address deficiencies, leading to improved unit performance and overall country development. The basic data envelopment analysis (DEA), which served as the basis for numerous modified DEA variations. The concept was developed by Charnes, Cooper, and Rhodes (1978) in their widely cited work. The problem is formulated in fractional form in the first step of DEA, then simplified to linear form (Panwar, Tin, & Pant, 2021). Efficient is the ratio of output to input in Equation (2).

$$Efficiency = \frac{outputs}{inputs} \quad (2)$$

However, real-life circumstances with various inputs and outputs make things complicated. DEA helps here by calculating efficiency as the weighted sum of output to input, formally represented as Equation (3).

$$Efficiency = \frac{weighted\ sum\ of\ outputs}{weighted\ sum\ of\ inputs} \quad (3)$$

Appendix C: Robustness Checks

C1. ICT-Development via Export Volume and Energy Efficiency

Next, we use another proxy of mediating variable, energy efficiency to test how well our predictions work by estimating the same structural equation. Table C1 shows that the direct effect of ICT measures on GDP is positive, while teleinfind and eparti have insignificant impact. When it comes to mediator trade, ICT has a positive and significant effect on the EXPVO, and the GDP in CAREC economies goes up with the rise in EXPVO. Most indicators of ICT have a negative effect on EEF except 1telesub. However, the influence of EEF on GDP is insignificant.

Table C1: SEM Estimates ICT-Development with EXPVO and EEF

Exogenous	Path	Endogenous	teleinfind	egovi	osindex	eparti	1telesub
ICT	→	EEF	-0.046*	-0.050	-0.016	-0.034**	0.040***
			(0.027)	(0.035)	(0.023)	(0.017)	(0.008)
EEF	→	GDP	-0.235	0.488	0.313	-0.021	-1.214
			(1.021)	(1.004)	(0.998)	(1.030)	(0.963)
EXPVO	→	GDP	1.029***	0.725***	0.748***	0.944***	0.599***
			(0.122)	(0.125)	(0.122)	(0.119)	(0.115)
ICT	→	GDP	-0.507	1.401***	0.898***	-0.036	0.703***
			(0.354)	(0.473)	(0.317)	(0.248)	(0.130)
ICT	→	EXPVO	1.806***	2.655***	1.909***	1.519***	0.653***
			(0.166)	(0.200)	(0.123)	(0.112)	(0.063)
Observations			0.003***	0.003***	0.003***	0.003***	0.003***
Var(e.EC)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			0.683***	0.662***	0.664***	0.690***	0.591***
Var(e.GDP)			(0.067)	(0.065)	(0.066)	(0.068)	(0.059)
			0.222***	0.189***	0.161***	0.186***	0.231***
Var(e.EXPVO)			(0.022)	(0.019)	(0.016)	(0.018)	(0.023)
Chi2(Model vs Saturated)			543***	542.1***	520.4***	590.9***	549.9***
R2 GDP			0.98	0.98	0.98	0.98	0.98
R2 EC			0.09	0.08	0.08	0.09	0.18
R2 Trade			0.44	0.52	0.59	0.53	0.49
R2 Overall			0.99	0.99	0.99	0.99	0.99

Note: see note to Table 4
Source: Author calculations

Figures 11-15 show the direct and indirect effects of ICT on GDP by using EXPVO and EEF as mediation variables. The coefficient between ICT (e-governance, online service index, fixed telephone subscriptions) and GDP is 1.401, 0.898, and 0.307 respectively, indicating the direct channel. However, the indirect impact of ICT on GDP through EXPVO and EEF is 1.869. In this way the total impact of ICT is 1.362 (tele infrastructure), 3.302 (e-governance), 2.320 (online service index), 1.399 (e-participation index), and 1.045 (fixed telephone subscriptions) on GDP. The relationship between EXPVO and GDP is positive and significant, which means that export volume led to improved GDP. Although, the coefficient between EEF and GDP is insignificant. This proves that trade and environmental quality has a mediating role in enhancing GDP, which was our original hypothesis.

Table C2 provides the structural equation parameter estimations for how ICT affects GDP directly and indirectly.

Figure 11

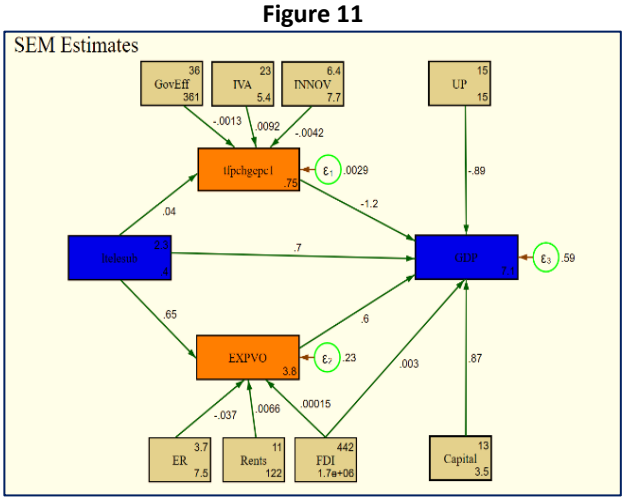


Figure 12

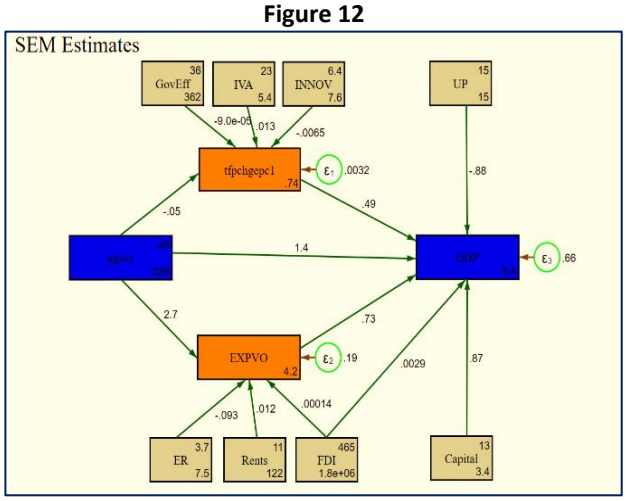


Figure 13

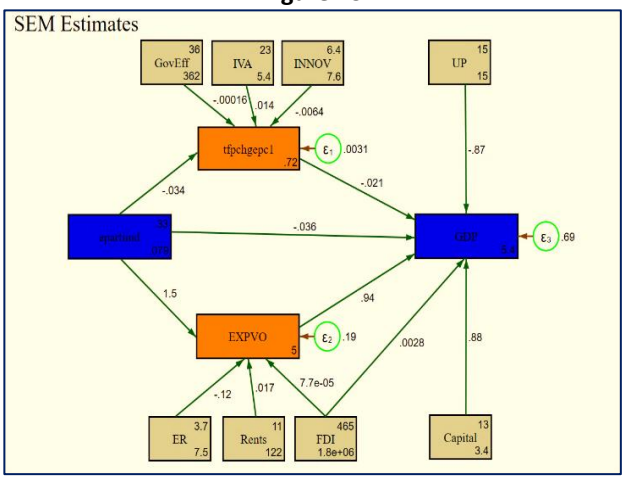


Figure 14

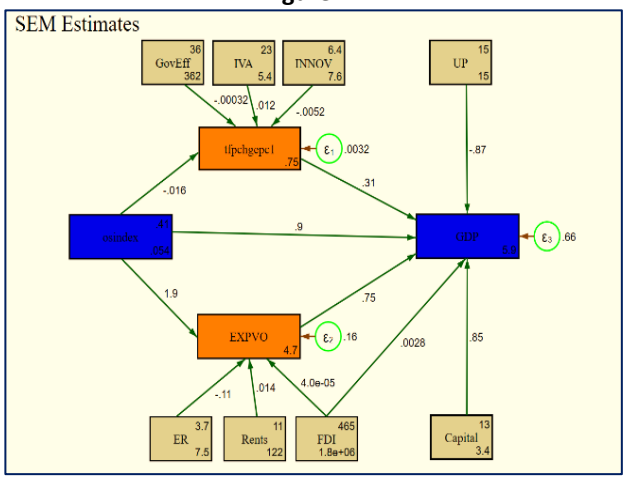
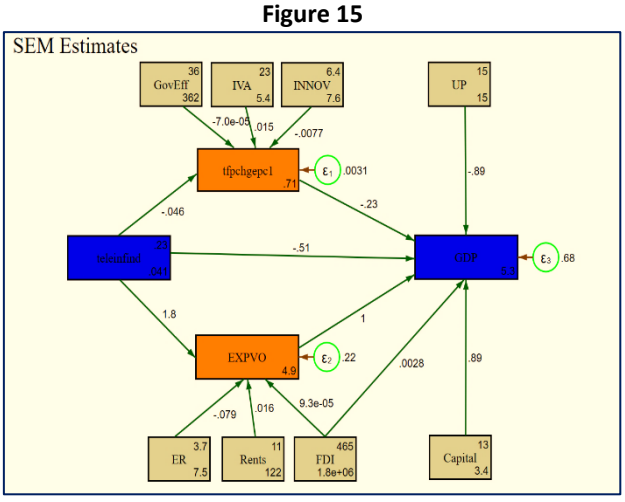


Figure 15



Source: Author construction

Table C2: Direct, Indirect and Total Effects from ICT to GDP through EXPVO and EEF

Exogenous Variable	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.507	1.869***	1.362***
ICT	EEF	-0.0459	-	-0.0459
ICT	EXPVO	1.806***	-	1.806***
EEF	GDP	-0.235	-	-0.235
EXPVO	GDP	1.806***	-	1.806***
E-Governance Index				
ICT	GDP	1.401**	1.901***	3.302***
ICT	EEF	-0.0501	-	-0.0501
ICT	EXPVO	2.655***	-	2.655***
EEF	GDP	0.488	-	0.488
EXPVO	GDP	0.725***	-	0.725***
Online Service Index				
ICT	GDP	0.898**	1.422***	2.320***
ICT	EEF	-0.0163	-	-0.0163
ICT	EXPVO	1.909***	-	1.909***
EEF	GDP	0.313	-	0.313
EXPVO	GDP	0.748***	-	0.748***
E-Participation Index				
ICT	GDP	-0.0357	1.435***	1.399***
ICT	EEF	-0.0338*	-	-0.0338*
ICT	EXPVO	1.519***	-	1.519***
EEF	GDP	-0.0213	-	-0.0213
EXPVO	GDP	0.944***	-	0.944***
Fixed Telephone Subscriptions				
ICT	GDP	0.703***	0.343***	1.045***
ICT	EEF	0.0401***	-	0.0401***
ICT	EXPVO	0.653***	-	0.653***
EEF	GDP	-1.214	-	-1.214
EXPVO	GDP	0.599***	-	0.599***

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculation

C2: ICT-Development via Export Volume and Ecological Footprint

The structural equation evaluated in Table C3 has both direct and indirect effects using EXPVO and EFP as mediation factors, which are shown in Table 8. The indicators of ICT (egovi, osindex, and 1telesub) have a net positive impact on GDP of 0.985, 0.616, and 0.644 respectively. ICT has a positive and significant impact on EXPVO and EFP. This finding matches with the earlier studies such as by Avom et al. (2020), Lee and Brahmasrene (2014) and Raheem et al. (2020). In return, these mediator variables have a positive and significant influence on GDP. In short, GDP is directly and indirectly impacted by ICT. Our hypothesis that ICT has a major impact on GDP is supported.

Table C3: SEM Estimates ICT-Development with EXPVO and EFP

Exogenous	Path	Endogenous	teleinfind	egovi	osindex	eparti	1telesub
ICT	→	EFP	1.643**	5.541***	2.444***	2.657***	0.582**
			(0.763)	(0.952)	(0.629)	(0.449)	(0.250)
EFP	→	GDP	0.143***	0.121***	0.122***	0.162***	0.134***
			(0.036)	(0.037)	(0.037)	(0.038)	(0.034)
EXPVO	→	GDP	0.906***	0.680***	0.698***	0.881***	0.501***
			(0.121)	(0.121)	(0.120)	(0.114)	(0.114)
ICT	→	GDP	-0.543	0.985**	0.616*	-0.403	0.644***
			(0.337)	(0.470)	(0.319)	(0.249)	(0.122)
ICT	→	EXPVO	1.806***	2.655***	1.909***	1.519***	0.653***
			(0.166)	(0.200)	(0.123)	(0.112)	(0.063)
Observations			2.587***	2.271***	2.464***	2.260***	2.585***
Var(e.EC)			(0.256)	(0.224)	(0.243)	(0.223)	(0.256)
			0.635***	0.629***	0.631***	0.635***	0.553***
Var(e.GDP)			(0.063)	(0.062)	(0.062)	(0.063)	(0.055)
			0.222***	0.189***	0.161***	0.186***	0.231***
Var(e.EXPVO)			(0.022)	(0.019)	(0.016)	(0.018)	(0.023)
Chi2(Model vs Saturated)			811***	728.1***	735.4***	728.5***	749.2***
R2 GDP			0.98	0.98	0.98	0.98	0.98
R2 EC			0.15	0.25	0.19	0.26	0.15
R2 Trade			0.44	0.52	0.59	0.53	0.42
R2 Overall			0.99	0.99	0.99	0.99	0.99

Note: see note to Table 4
Source: Author calculation

Figures 16-20 show the direct and indirect effects of ICT on GDP. The coefficients between ICT and GDP are positive and significant as 0.985 (e-governance) and 0.644 (fixed telephone subscriptions), which shows the direct route. But ICT has an indirect effect on GDP of 1.870, 2.479, 1.631, 1.770, and 0.664 (in all dimensions of ICT) through EXPVO and EFP. In this way, ICT has a total effect on GDP of 1.327 (tele infrastructure), 3.464 (e-governance), 2.247 (online service index), 1.366 (e-participation index), and 0.644. The impact of EXPVO and EFP on GDP are positive and significant, which means that the increase in export volume and improved environmental quality led to a rise in GDP. Table C4 shows the estimated structural equation parameters for how ICT affects GDP.

Figure 16

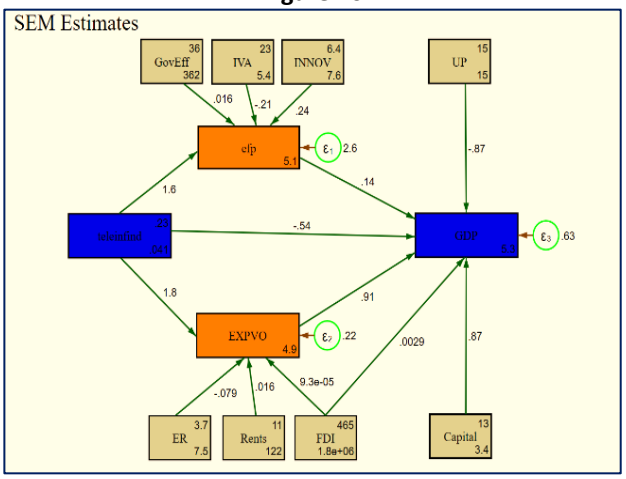


Figure 17

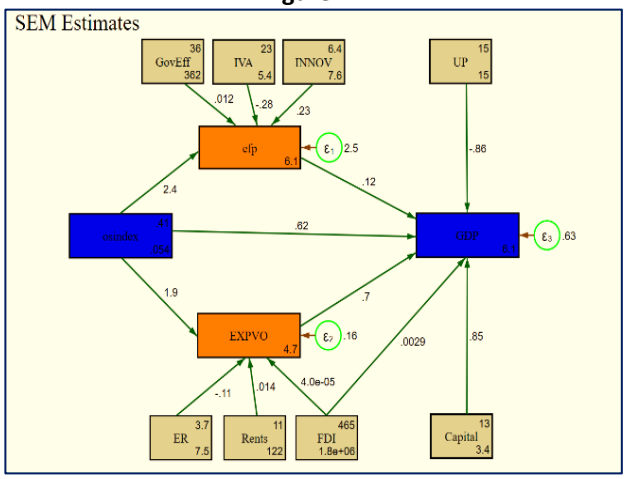


Figure 18

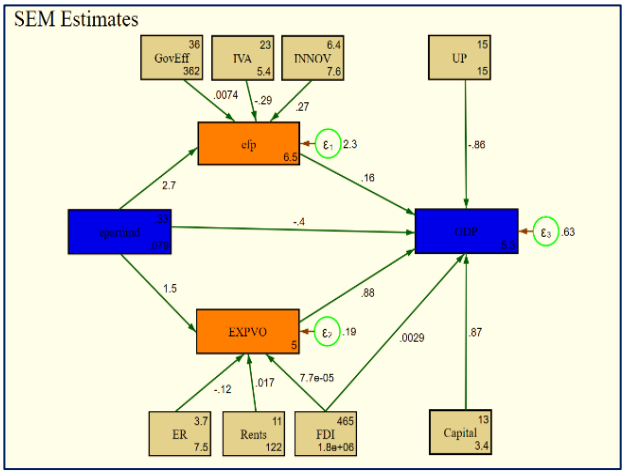


Figure 19

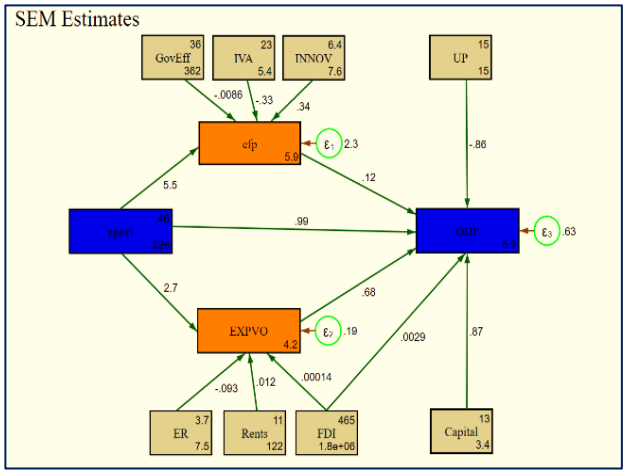
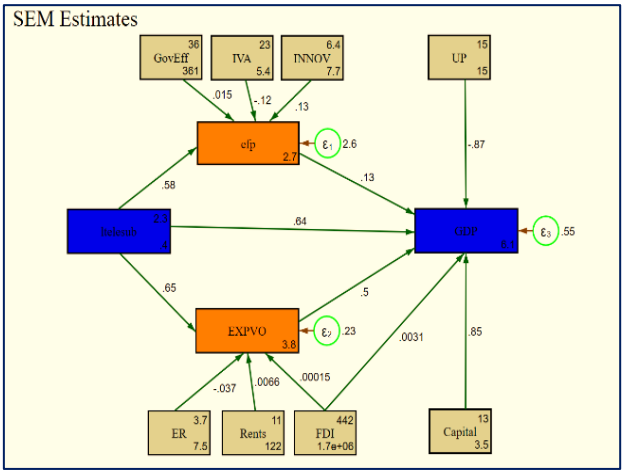


Figure 20



Source: Author construction

Table C4: Direct, Indirect, and Total Effects from ICT to GDP through EXPVO and EFP

Exogenous Variable	Endogenous	Direct Effects		Indirect Effects	Total Effects
Tele Infrastructure Index					
ICT	GDP	-0.543		1.870***	1.327***
ICT	EFP	1.643*			1.643*
ICT	EXPVO	1.806***			1.806***
EFP	GDP	0.143***			0.143***
EXPVO	GDP	0.906***			**0.906*** **
E-Governance Index					
ICT	GDP	0.985*		2.479***	3.464***
ICT	EFP	5.541***			5.541***
ICT	EXPVO	2.655***			2.655***
EFP	GDP	0.121**			0.121**
EXPVO	GDP	0.680***			0.680***
Online Service Index					
ICT	GDP	0.616		1.631***	2.247***
ICT	EFP	2.444***		-	2.444***
ICT	EXPVO	1.909***		-	1.909***
EFP	GDP	0.122**		-	0.122**
EXPVO	GDP	0.698***		-	0.698***
E-Participation Index					
ICT	GDP	-0.403		1.770***	1.366***
ICT	EFP	2.657***		-	2.657***
ICT	EXPVO	1.519***		-	1.519***
EFP	GDP	0.162***		-	0.162***
EXPVO	GDP	0.881***		-	0.881***
Fixed Telephone Subscriptions					
ICT	GDP	0.644***	0.405***	0.644***	0.644***
ICT	EFP	0.582*		-	0.582*
ICT	EXPVO	0.653***		-	0.653***
EFP	GDP	0.134***		-	0.134***
EXPVO	GDP	0.501***		-	0.501***

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculations

C3: ICT-Development via Import Volume and Energy Efficiency

Table C5 demonstrates that the model fits well, the variables and relationships can be explained, and the exogenous and endogenous variable settings are plausible. Results show that the structural equation being considered has both direct and indirect effects, which are mediated by IMPVO and EEF. The ICT measures have a net positive effect on GDP and IMPVO. ICT has a mixed effect on EEF. In turn, the total impact of these factors on GDP is positive and significant.

Table C5: SEM Estimates ICT-Development with IMPVO and EEF

Exogenous Variable	Path	Endogenous Variable	teleinfind	egovi	osindex	eparti	1telesub
ICT	→	EEF	-0.046*	-0.050	-0.016	-0.034**	0.040***
			(0.027)	(0.035)	(0.023)	(0.017)	(0.008)
EEF	→	GDP	0.439	1.784*	1.200	0.723	-1.638
			(1.186)	(1.085)	(1.087)	(1.189)	(1.022)
IMPVO	→	GDP	0.304*	-0.365**	-0.247	0.220	0.018
			(0.160)	(0.159)	(0.155)	(0.157)	(0.112)
ICT	→	GDP	0.446	4.033***	2.431***	0.593*	1.060***
			(0.476)	(0.620)	(0.413)	(0.335)	(0.129)
ICT	→	IMPVO	2.035***	2.942***	1.937***	1.616***	0.501***
			(0.146)	(0.169)	(0.114)	(0.100)	(0.067)
Observations							
Var(e.EC)			0.003***	0.003***	0.003***	0.003***	0.003***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Var(e.GDP)			0.903***	0.752***	0.776***	0.893***	0.670***
			(0.089)	(0.074)	(0.077)	(0.088)	(0.066)
Var(e.IMPVO)			0.171***	0.135***	0.139***	0.148***	0.264***
			(0.017)	(0.013)	(0.014)	(0.015)	(0.026)
Chi2(Model vs Saturated)			524.05***	476.5***	499.7***	531.2***	510.09***
R2 GDP			0.98	0.98	0.98	0.98	0.98
R2 EC			0.09	0.27	0.08	0.08	0.17
R2 Trade			0.55	0.64	0.64	0.63	0.31
R2 Overall			0.99	0.99	0.99	0.99	0.99

Note: see note to Table 4
Source: Author calculations

According to Figures 26-30, ICT has a significant, beneficial impact on economic growth with standardized path coefficients of 4.033 (e-governance) and 2.431 (online service index). However, the indirect impact of ICT on GDP is mostly insignificant with the mediating roles of IMPVO and EEF. The total effect of ICT is positive and significant with all proxies of ICT. Table C6 shows that the model fits well, that the variables and their relationships can be explained fairly, and that the choices for the exogenous and endogenous variables make sense.

Figure 26

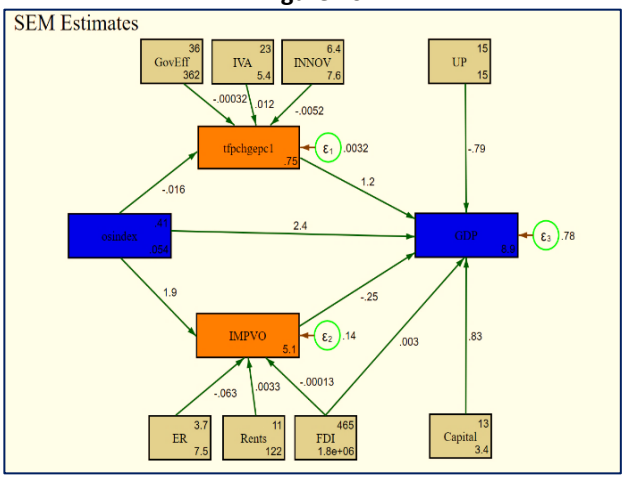


Figure 27

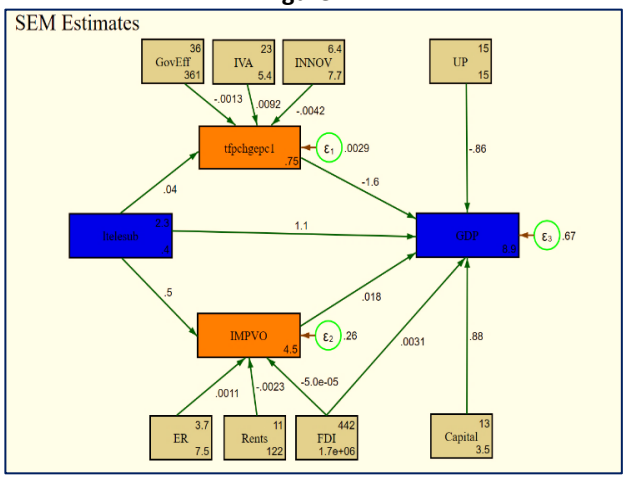


Figure 28

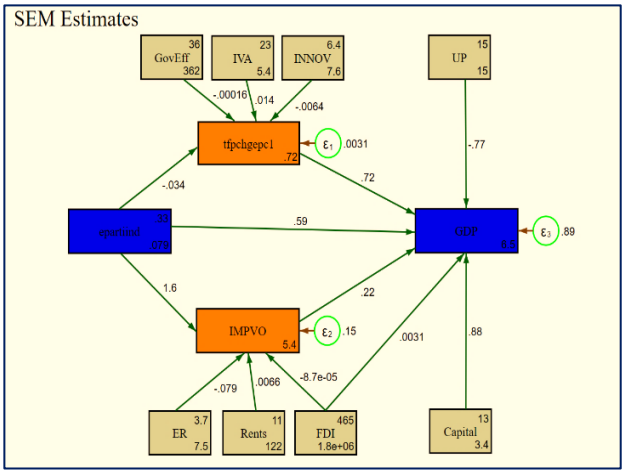


Figure 29

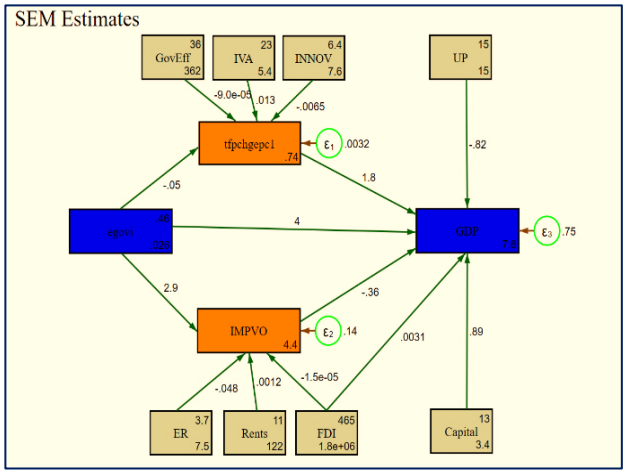
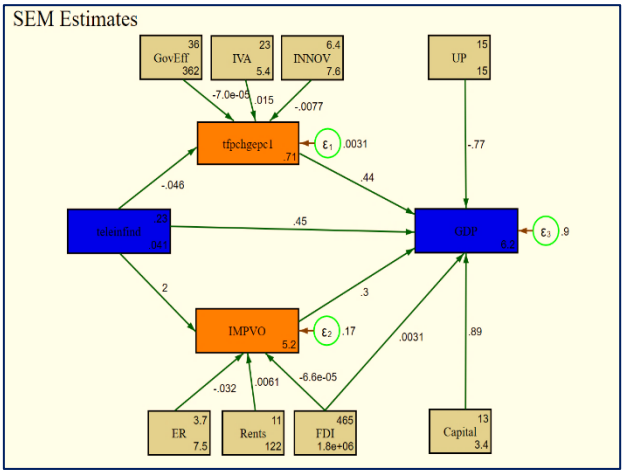


Figure 30



Source: Author construction

Table C6: Direct, Indirect, and Total Effects from ICT to GDP through IMPVO and EEF

Exogenous Variable	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	0.446	0.598	1.044**
ICT	EEF	-0.0459	-	-0.0459
ICT	IMPVO	2.035***	-	2.035***
EEF	GDP	0.439	-	0.439
IMPVO	GDP	0.304	-	0.304
E-Governance Index				
ICT	GDP	4.033***	-1.162*	2.871***
ICT	EEF	-0.0501	-	-0.0501
ICT	IMPVO	2.942***	-	2.942***
EEF	GDP	1.784	-	1.784
IMPVO	GDP	-0.365*	-	-0.365*
Online Service Index				
ICT	GDP	2.431***	-0.499	1.932***
ICT	EEF	-0.0163	-	-0.0163
ICT	IMPVO	1.937***	-	1.937***
EEF	GDP	1.200	-	1.200
IMPVO	GDP	-0.247	-	-0.247
E-Participation Index				
ICT	GDP	0.593	0.332	0.924***
ICT	EEF	-0.0338*	-	-0.0338*
ICT	IMPVO	1.616***	-	1.616***
EEF	GDP	0.723	-	0.723
IMPVO	GDP	0.220	-	0.220
Fixed Telephone Subscriptions				
ICT	GDP	1.060***	-0.0568	1.003***
ICT	EEF	0.0401***	-	0.0401***
ICT	IMPVO	0.501***	-	0.501***
EEF	GDP	-1.638	-	-1.638
IMPVO	GDP	0.0177	-	0.0177

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculation

C4: ICT-Development via Import Volume and Ecological Footprint

Table C7 shows the SEM values that were made using teleinfind, egovi, osindex, eparti, and 1telesub as ICT proxies. The results showed that the direct effect of ICT measures on GDP is positive and significant with egovi, osindex, and 1telesub. When it comes to trade, ICT has a positive effect on the import volume index, and the GDP in CAREC economies goes up when the IMPVO goes up. Similarly, all indicators of ICT have a good effect on EFP. The impact of EFP on GDP is positive and significant in all cases of ICT.

Table C7: SEM Estimates ICT-Development with IMPVO and EFP

Exogenous Variable	Path	Endogenous Variable	teleinfind	egovi	osindex	eparti	1telesub
ICT	→	EFP	1.643**	5.541***	2.444***	2.657***	0.582**
			(0.763)	(0.952)	(0.629)	(0.449)	(0.250)
EFP	→	GDP	0.203***	0.143***	0.148***	0.210***	0.172***
			(0.039)	(0.039)	(0.040)	(0.043)	(0.034)
IMPVO	→	GDP	0.220	-0.265*	-0.180	0.314**	-0.054
			(0.149)	(0.152)	(0.149)	(0.146)	(0.107)
ICT	→	GDP	0.272	3.096***	1.862***	-0.116	0.943***
			(0.438)	(0.620)	(0.418)	(0.335)	(0.120)
ICT	→	IMPVO	2.035***	2.942***	1.937***	1.616***	0.501***
			(0.146)	(0.169)	(0.114)	(0.100)	(0.067)
Observations							
Var(e.EC)			2.587***	2.271***	2.464***	2.260***	2.585***
			(0.256)	(0.224)	(0.243)	(0.223)	(0.256)
Var(e.GDP)			0.800***	0.715***	0.731***	0.801***	0.605***
			(0.079)	(0.071)	(0.072)	(0.079)	(0.060)
Var(e.IMPVO)			0.171***	0.135***	0.139***	0.148***	0.264***
			(0.017)	(0.013)	(0.014)	(0.015)	(0.026)
Chi2(Model vs Saturated)			704.2***	646.2***	692***	690.7***	690.05***
R2 GDP			0.98	0.98	0.98	0.98	0.98
R2 EC			0.15	0.25	0.19	0.26	0.15
R2 Trade			0.53	0.64	0.63	0.61	0.31
R2 Overall			0.99	0.99	0.99	0.99	0.99

Note: see note to Table 4
Source: Author calculations

Figures 31-35 show that, apart from the tele infrastructure index and e-participation index, the direct effect of ICT measures on GDP is positive. ICT (tele infrastructure index and e-participation index) has a good and significant indirect effect on GDP through exports and the EFP. In the same way, the total effect is also positive and significant in all ICT proxies. With all proxies of ICT have path coefficients for IMPVO and EFP with positive, significant impact and upward direction. Table C8 shows the parameter estimates for the structure equation that shows how ICT changes GDP.

Figure 31

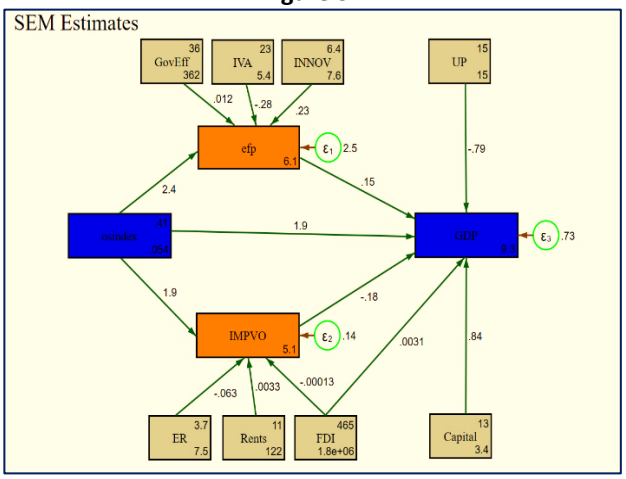


Figure 32

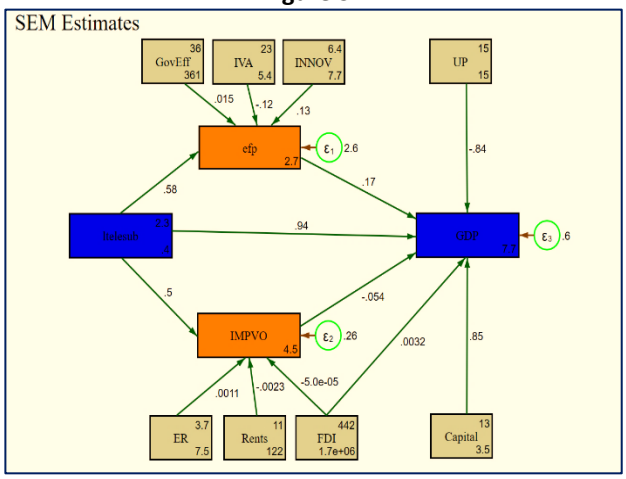


Figure 33

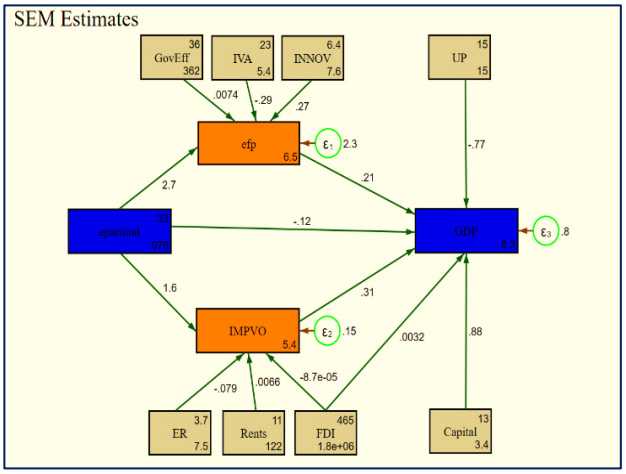


Figure 34

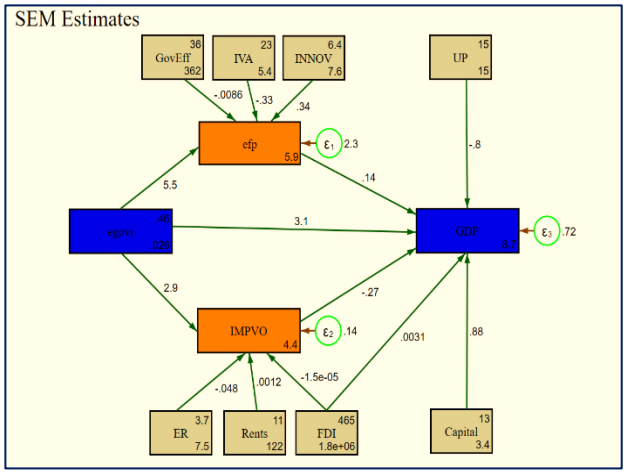
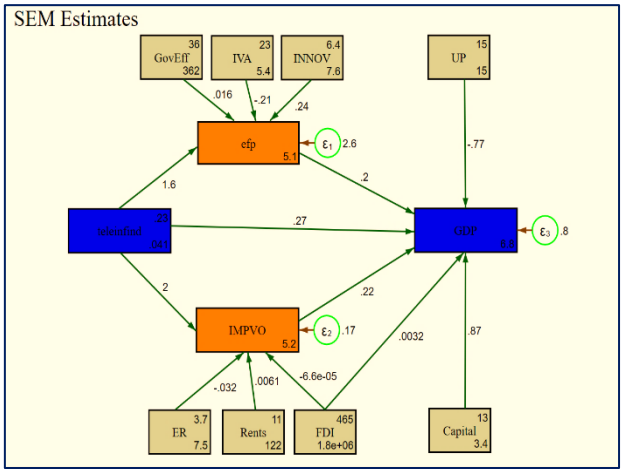


Figure 35



Source: Author construction

Table C8: Direct, Indirect, and Total Effects from ICT to GDP through IMPVO and EFP

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	0.272	0.782*	1.054**
ICT	EFP	1.643*	-	1.643*
ICT	IMPVO	2.035***	-	2.035***
EFP	GDP	0.203***	-	0.203***
IMPVO	GDP	0.220	-	0.220
E-Governance Index				
ICT	GDP	3.096***	0.0146	3.111***
ICT	EFP	5.541***	-	5.541***
ICT	IMPVO	2.942***	-	2.942***
EFP	GDP	0.143***	-	0.143***
IMPVO	GDP	-0.265	-	-0.265
Online Service Index				
ICT	GDP	1.862***	0.0128	1.875***
ICT	EFP	2.444***	-	2.444***
ICT	IMPVO	1.937***	-	1.937***
EFP	GDP	0.148***	-	0.148***
IMPVO	GDP	-0.180	-	-0.180
E-Participation Index				
ICT	GDP	-0.116	1.066***	0.950***
ICT	EFP	2.657***	-	2.657***
ICT	IMPVO	1.616***	-	1.616***
EFP	GDP	0.210***	-	0.210***
IMPVO	GDP	0.314*	-	0.314*
Fixed Telephone Subscriptions				
ICT	GDP	0.943***	0.0731	1.016***
ICT	EFP	0.582*	-	0.582*
ICT	IMPVO	0.501***	-	0.501***
EFP	GDP	0.172***	-	0.172***
IMPVO	GDP	-0.0543	-	-0.0543

Note: * p<0.05, ** p<0.01, *** p<0.001, Source: Author calculation

Table C9: Direct, Indirect, and Total Effects from ICT to GDP through EC and Exports

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.547**	3.118***	2.571***
ICT	EC	1.021***	-	1.021***
ICT	EXPORTS	4.143***	-	4.143***
EC	GDP	0.530***	-	0.530***
EXPORTS	GDP	0.622***	-	0.622***
E-Governance Index				
ICT	GDP	-0.232	5.717***	5.485***
ICT	EC	2.889***	-	2.889***
ICT	EXPORTS	6.942***	-	6.942***
EC	GDP	0.526***	-	0.526***
EXPORTS	GDP	0.604***	-	0.604***
Online Service Index				
ICT	GDP	-0.303	4.144***	3.841***
ICT	EC	1.109***	-	1.109***
ICT	EXPORTS	5.765***	-	5.765***
EC	GDP	0.540***	-	0.540***
EXPORTS	GDP	0.615***	-	0.615***
E-Participation Index				
ICT	GDP	-0.504***	2.778***	2.274***
ICT	EC	0.762***	-	0.762***
ICT	EXPORTS	3.773***	-	3.773***
EC	GDP	0.567***	-	0.567***
EXPORTS	GDP	0.622***	-	0.622***
Fixed Telephone Subscriptions				
ICT	GDP	0.222**	1.630***	1.852***
ICT	EC	0.749***	-	0.749***
ICT	EXPORTS	2.317***	-	2.317***
EC	GDP	0.457***	-	0.457***
EXPORTS	GDP	0.556***	-	0.556***

Note: * p<0.05, ** p<0.01, *** p<0.001. Source: Author calculation

Table C10: Direct, Indirect, and Total Effects from ICT to GDP through EEF and Exports

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.480*	3.523***	3.042***
ICT	EEF	-0.0459	-	-0.0459
ICT	EXPORTS	4.143***	-	4.143***
EEF	GDP	-0.729	-	-0.729
EXPORTS	GDP	0.842***	-	0.842***
E-Governance Index				
ICT	GDP	0.114	5.576***	5.690***
ICT	EEF	-0.0501	-	-0.0501
ICT	EXPORTS	6.942***	-	6.942***
EEF	GDP	-0.461	-	-0.461
EXPORTS	GDP	0.800***	-	0.800***
Online Service Index				
ICT	GDP	-0.0114	4.679***	4.668***
ICT	EEF	-0.0163	-	-0.0163
ICT	EXPORTS	5.765***	-	5.765***
EEF	GDP	-0.507	-	-0.507
EXPORTS	GDP	0.810***	-	0.810***
E-Participation Index				
ICT	GDP	-0.324*	3.208***	2.885***
ICT	EEF	-0.0338*	-	-0.0338*
ICT	EXPORTS	3.773***	-	3.773***
EEF	GDP	-0.764	-	-0.764
EXPORTS	GDP	0.843***	-	0.843***
Fixed Telephone Subscriptions				
ICT	GDP	0.400***	1.596***	1.996***
ICT	EEF	0.0401***	-	0.0401***
ICT	EXPORTS	2.317***	-	2.317***
EEF	GDP	-1.170	-	-1.170
EXPORTS	GDP	0.709***	-	0.709***

Note: * p<0.05, ** p<0.01, *** p<0.001. Source: Author calculation

Table C11: Direct, Indirect, and Total Effects from ICT to GDP through EFP and Exports

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.444*	3.480***	3.036***
ICT	EFP	1.643*	-	1.643*
ICT	EXPORTS	4.143***	-	4.143***
EFP	GDP	-0.00829	-	-0.00829
EXPORTS	GDP	0.843***	-	0.843***
E-Governance Index				
ICT	GDP	0.171	5.508***	5.679***
ICT	EFP	5.541***	-	5.541***
ICT	EXPORTS	6.942***	-	6.942***
EFP	GDP	-0.0124	-	-0.0124
EXPORTS	GDP	0.803***	-	0.803***
Online Service Index				
ICT	GDP	0.0210	4.660***	4.681***
ICT	EFP	2.444***	-	2.444***
ICT	EXPORTS	5.765***	-	5.765***
EFP	GDP	-0.0105	-	-0.0105
EXPORTS	GDP	0.813***	-	0.813***
E-Participation Index				
ICT	GDP	-0.303	3.161***	2.858***
ICT	EFP	2.657***	-	2.657***
ICT	EXPORTS	3.773***	-	3.773***
EFP	GDP	0.00673	-	0.00673
EXPORTS	GDP	0.833***	-	0.833***
Fixed Telephone Subscriptions				
ICT	GDP	0.366***	1.655***	2.021***
ICT	EFP	0.582*	-	0.582*
ICT	EXPORTS	2.317***	-	2.317***
EFP	GDP	-0.00334	-	-0.00334
EXPORTS	GDP	0.715***	-	0.715***

Note: * p<0.05, ** p<0.01, *** p<0.001. Source: Author calculation

Table C12: Direct, Indirect, and Total Effects from ICT to GDP through EC and Imports

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.942***	3.355***	2.413***
ICT	EC	1.021***	-	1.021***
ICT	IMPORTS	3.874***	-	3.874***
EC	GDP	0.910***	-	0.910***
IMPORTS	GDP	0.626***	-	0.626***
E-Governance Index				
ICT	GDP	-1.138**	7.043***	5.905***
ICT	EC	2.889***	-	2.889***
ICT	IMPORTS	6.653***	-	6.653***
EC	GDP	0.942***	-	0.942***
IMPORTS	GDP	0.649***	-	0.649***
Online Service Index				
ICT	GDP	-0.794**	4.429***	3.636***
ICT	EC	1.109***	-	1.109***
ICT	IMPORTS	5.293***	-	5.293***
EC	GDP	0.956***	-	0.956***
IMPORTS	GDP	0.637***	-	0.637***
E-Participation Index				
ICT	GDP	-0.822***	2.908***	2.086***
ICT	EC	0.762***	-	0.762***
ICT	IMPORTS	3.438***	-	3.438***
EC	GDP	0.963***	-	0.963***
IMPORTS	GDP	0.633***	-	0.633***
Fixed Telephone Subscriptions				
ICT	GDP	0.174	1.594***	1.768***
ICT	EC	0.749***	-	0.749***
ICT	IMPORTS	2.091***	-	2.091***
EC	GDP	0.831***	-	0.831***
IMPORTS	GDP	0.465***	-	0.465***

Note: * p<0.05, ** p<0.01, *** p<0.001. Source: Author calculation

Table C13: Direct, Indirect, and Total Effects from ICT to GDP through EEF and Imports

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.641*	3.534***	2.893***
ICT	EEF	3.874***	-	3.874***
ICT	IMPORTS	-0.0459	-	-0.0459
EEF	GDP	-0.0256	-	-0.0256
IMPORTS	GDP	0.912***	-	0.912***
E-Governance Index				
ICT	GDP	0.274	5.243***	5.517***
ICT	EEF	-0.0501	-	-0.0501
ICT	IMPORTS	6.653***	-	6.653***
EEF	GDP	0.329	-	0.329
IMPORTS	GDP	0.791***	-	0.791***
Online Service Index				
ICT	GDP	0.265	4.116***	4.381**
ICT	EEF	-0.0163	-	-0.0163
ICT	IMPORTS	5.293***	-	5.293***
EEF	GDP	0.322	-	0.322
IMPORTS	GDP	0.779***	-	0.779***
E-Participation Index				
ICT	GDP	-0.267	3.012***	2.744***
ICT	EEF	-0.0338*	-	-0.0338*
ICT	IMPORTS	3.438***	-	3.438***
EEF	GDP	0.0505	-	0.0505
IMPORTS	GDP	0.877***	-	0.877***
Fixed Telephone Subscriptions				
ICT	GDP	0.622***	1.240***	1.862**
ICT	EEF	0.0401***	-	0.0401***
ICT	IMPORTS	2.091***	-	2.091***
EEF	GDP	-0.924	-	-0.924
IMPORTS	GDP	0.611***	-	0.611***

Note: * p<0.05, ** p<0.01, *** p<0.001. Source: Author calculation

Table C14: Direct, Indirect, and Total Effects from ICT to GDP through EFP and Imports

Exogenous	Endogenous	Direct Effects	Indirect Effects	Total Effects
Tele Infrastructure Index				
ICT	GDP	-0.700*	3.437***	2.736***
ICT	EFP	1.643*	-	1.643*
ICT	IMPORTS	3.874***	-	3.874***
EFP	GDP	0.129***	-	0.129***
IMPORTS	GDP	0.832***	-	0.832***
E-Governance Index				
ICT	GDP	-0.178	5.810***	5.632***
ICT	EFP	5.541***	-	5.541***
ICT	IMPORTS	6.653***	-	6.653***
EFP	GDP	0.128***	-	0.128***
IMPORTS	GDP	0.767***	-	0.767***
Online Service Index				
ICT	GDP	-0.0389	4.283***	4.244***
ICT	EFP	2.444***	-	2.444***
ICT	IMPORTS	5.293***	-	5.293***
EFP	GDP	0.126***	-	0.126***
IMPORTS	GDP	0.751***	-	0.751***
E-Participation Index				
ICT	GDP	-0.635**	3.294***	2.658***
ICT	EFP	2.657***	-	2.657***
ICT	IMPORTS	3.438***	-	3.438***
EFP	GDP	0.159***	-	0.159***
IMPORTS	GDP	0.835***	-	0.835***
Fixed Telephone Subscriptions				
ICT	GDP	0.567***	1.214***	1.782***
ICT	EFP	0.582*	-	0.582*
ICT	IMPORTS	2.091***	-	2.091***
EFP	GDP	0.117***	-	0.117***
IMPORTS	GDP	0.548***	-	0.548***

Note: * p<0.05, ** p<0.01, *** p<0.001. Source: Author calculation

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