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Does Information Technology Contribute to Improving the Quality of Education? Empirical Analysis from Saudi Arabia

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ABSTRACT
The most significant visible innovation in this globalization period has been Information and Communication Technology (ICT). It has transformed the world into a global village with limitless connectivity, interactive organizations, knowledge exchange, and worldwide access. It is both a cross-cutting concern and a necessary tool for social and economic progress. For decades, ICT has played a vital role in job creation, job skill development, and manufacturing. Adopting ICT may significantly reduce a society's corruption, resulting in a forward-thinking government in the country. Many individuals' lives and livelihoods, particularly those in rural regions, cannot be enhanced without utilizing the ICT scope. However, a developing country like Saudi Arabia, with enormous potential, is still distant from adopting ICT, despite numerous challenges, when the entire globe is developing with the blessings of ICT. The present study has presented a complete empirical examination of information and communication in developing nations, focusing on Saudi Arabia. This study applied econometric analysis to examine the role of ICT in improving the quality of education in Saudi Arabia for the period 1990-2022. This study employed a vector error correction model (VECM) approach for empirical estimation. This study concluded that ICT contributed significantly to improving the education index in Saudi Arabia. It is recommended that policymakers of developing countries divert their attention towards ICT-related investment to enhance the level of education index.

Keywords: Developing Nation, Education, Information and Communication Technology, Quality of Education.

1. Introduction

Information and Communication Technology (ICT) has aided in civilization's growth, dramatically altering how we live, particularly in industrialized countries (Carrión-Martínez et al., 2020). These technologies influence how we interact, connect, and work and are critical to the growth of sectors including health, economics, and education (Nevado-Peña et al., 2019). Thus, ICTs touch people's everyday lives on an individual level. Still, at the macro level, these tools seek to help construct a more sustainable future by eliminating poverty and enhancing many people's education, health, and standard of living (Fernandez-Portillo et al., 2019). Mobile terminals and sensor devices are connected to the Internet as mobile network speeds increase and cloud computing and Internet of Things applications gain popularity. The unprecedented interconnectedness of gadgets has

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been accomplished, and the amount of data created is incalculable (Zhang et al., 2021). In the twenty-first century, the level of education has become the most important factor in determining whether a country is weak or strong.

Technology is becoming more prevalent in several spheres of society, influencing people's everyday lives, which is reflected in transformations in the educational area. These advancements have permitted the creation of innovative educational techniques that enhance students' teaching-learning processes (Carrión-Martínez et al., 2020). The educational sector has been significantly affected by advancements in ICT. According to Voogt et al. (2015), the educational system can undergo a complete transformation by using ICT because it is capable of adjusting to the individual needs of each student. The new educational approaches strive for equality and tolerance for individual diversity. This would be impossible without incorporating technology into education that encourages the creation of novel ways and types of learning methods that eliminate inequities and promote more inclusivity in education (Ibujés Villacís and Franco Crespo, 2019). Understanding the level of ICT integration within classrooms is important, but it is just as vital to explore how this integration relates to better educational results, including enhanced student achievement, critical thinking abilities, and increased engagement (Hwang & Chen, 2017; Baniawwad et al., 2023). Therefore, the focus should not only be on incorporating ICT into the class settings but also on suggesting strategic modifications that improve people's well-being and long-term sustainability. On the other hand, the difficulty in embracing change due to different cultural traditions makes it hard for countries to adopt new technologies. Consequently, cultural barriers pose additional challenges to the use of ICT learning and technology in Saudi Arabia (Jin, 2010). Conservative segregation of women is a prominent aspect of Saudi society, which extends across streets, restaurants, workplaces, educational settings, and even domestic settings. This gender-segregated structure can lead to unequal access to ICT, diminished digital literacy, and restricted opportunities for women to participate in or gain from technological advancements, which in turn slows the overall adoption of ICT in the country.

In recent years, sustainable development has attracted growing attention in educational settings after establishment of goals by the United Nations Organization to address critical societal, including alleviating poverty, ensuring high-standard education, inclusivity, and reducing inequalities. These objectives give the educational community a fresh chance to build effective educational practices targeted at enhancing teaching and educating in a sustainable environment (Carrión-Martínez et al., 2020). All of this necessitates modifications in educational curricula, including measures such as technology integration. Education is critical for addressing societal issues and achieving long-term growth. This evolution can take place through technology education, which can help to provide a plethora of learning options. Given the increased interest and research on the topic of ICT in educational settings to achieve sustainability, this research was conducted to investigate the adoption of ICT in classrooms to promote more sustainable educational practices. AlMunajjed (2009) mentioned that religion and gender segregation are an integral part of Saudi Arabian culture and education thus ICT implementation in the country should be considered in light of these cultural factors.

ICT is both a universal concern and a critical instrument for economic progress in the age of globalization. It can play a significant role in job creation, job skill development, and increased output. Using ICT has the potential to promote more transparent, public-centered, and future-oriented government in the economy. By facilitating ICT equipment, many persons' lives and livelihoods, particularly those living in rural regions, can be improved. Overall, it may provide openness and accountability at all levels of society and government. Introducing ICT initiatives involves overcoming several challenges, and it is essential to recognize and address these hurdles effectively. To alleviate educational barriers in developing countries, it is necessary to evaluate factors like infrastructure, technological readiness, teacher training, and cultural norms (Alzahrani, 2019; Alabdulkarim et al., 2021). This study presents an empirical examination of ICT sectors in emerging nations, like Saudi Arabia serving as case studies. The two primary reasons for selecting this nation are research areas of interest and information accessibility. It should be mentioned that Saudi Arabia is classified as a developing country (as it still faces challenges related to economic diversification, social reforms, and sustainability). The main objective of this article is to examine the evolution of this nation's ICT sectors. It is believed that the study will assist developing nations in recognizing their constraints, allowing decision-makers to prepare effectively for the digitization of their vision for 2030. Based on the findings, some recommendations would be given to help them develop their ICT sectors.

2. Literature Review

2.1 ICT and Sustainable Development in Developing Country

Saudi Arabia is deeply committed to realizing the objectives of the 2030 Sustainable Development Agenda. The country is actively pursuing innovative strategies aligned with the Saudi Vision 2030 to foster a vibrant society, a prosperous nation, and a globally competitive economy. Within the framework of Vision 2030, the education sector holds paramount importance, with an emphasis on improving curricula, advancing higher education, and bolstering workforce skills. The overarching aim is to elevate educational standards on a global scale and empower individuals to navigate their professional pathways. As highlighted by Abubakar et al. (2020), there is a call for broader recognition of academic institutions, advocating for the inclusion of the top two hundred universities worldwide in university rankings.

There is a growing imperative for the educational sector to embed digital tools within their educational frameworks, with the rise of a digitally adept generation, including individuals accustomed to various technologies like games and smartphones (Alshammari et al., 2023). Consequently, the evolution of technology has reshaped learning approaches, offering improved comprehension, seamless access to diverse online resources, flexible study schedules, and the integration of supportive learning aids (Nami & Vaezi, 2018). The educational sectors are leveraging emerging technologies including, data analytics, big data, artificial intelligence, and blockchain to propel educational practices forward (Muhammad & Al Dabbagh, 2021). The utilization of technology in both curricular and extracurricular domains plays a pivotal role, offering strategic advantages (Muhammad & Al Dabbagh, 2021). Advancements in internet connectivity and wireless technology have facilitated widespread connectivity among mobile devices like laptops and tablets, fostering opportunities for convenient online learning (Hinostroza et al., 2016). This shift has notably catalyzed the adoption of distance learning methodologies by numerous institutions worldwide, with recognized environmental benefits stemming from the embrace of online education (Bataeineh & Aga, 2023).

2.2 ICT and Education

Utilizing technology to foster learning can yield benefits, particularly considering the tech-savvy and enthusiastic nature of today's youth. Ruthotto et al. (2021) investigated the driving factors motivating learners toward technological adoption in education, identifying learning, empowerment, and communication as key elements. These factors resonate with students who appreciate real-time interactions and connectivity facilitated by digital devices and the internet. Furthermore, Bereiter and Scardamalia (2006) suggested that technological integration into higher education can improve learners' critical-thinking skills, self-regulation, and interpersonal skill growth. One of the previous studies highlighted an education and technology are positively correlated, reflecting the importance of adapting curricula to leverage emerging technologies (Muhammad & Al Dabbagh, 2021). Similarly, several technological trends are accelerating adoption in the educational sector, including blended learning, learning space redesign, the evolution of online learning, student-led creation, and the integration of formal and informal learning (Castro, 2019).

The educational sector's role in advancing sustainable development has garnered increasing recognition, particularly within the educational sector (El Bedawy, 2014). It serves as a pivotal hub for promoting sustainability on a global scale, with sustainability understood to encompass environmental, societal, and economic dimensions (El Bedawy, 2014; Yousaf et al., 2021). The imperative for sustainability gained prominence following the Rio Earth Summit, in 1992, which underscored the importance of ecological conservation and the strategic role of the educational sector in this endeavor. Today, sustainability is integral to global developmental agendas, with the educational sector serving as a crucial partner in its realization due to its capacity for innovation, knowledge dissemination, and specialized skill development (Boström et al., 2018; Eizaguirre et al., 2019). Consequently, educational sectors are tasked with reforming their teaching and research methodologies, with curricular revisions aimed at integrating sustainability principles through innovative and technology-enabled pedagogical approaches (Sady et al., 2019).

Saudi Arabia has demonstrated its firm dedication to economic diversification and sustainable development through initiatives such as Vision 2030, aligned with the SDGs and the 2030 sustainable development agenda, in pursuit of comprehensive development (Bataeineh & Aga, 2023). However, a significant obstacle lies in the inadequacies of the education system, with Saudi graduates found to possess insufficient skills, resulting in reduced competitiveness on the global stage (Bataeineh & Aga, 2023). Nevertheless, Vision 2030 has acknowledged these educational challenges and implemented robust plans and investments to address them effectively. Substantial improvements have been observed in the education sector, including the development of new curricula aligned with international standards in ICT, the promotion of higher education, and the enhancement of skills relevant to the labor market.

Current breakthroughs in educational technology have paved the way for the emergence of various innovative tools and techniques aimed at enriching the learning experience (Nami & Vaezi, 2018; Ruthotto et al., 2021):

- Educational institutions now utilize analytics technologies to monitor students' progress and adapt teaching methods accordingly.
- Effective use of ICT significantly enhances educational opportunities in rural areas, and offers broad access to resources, ultimately bridging the digital divide between urban and rural educational settings.
- in educational settings bridges the digital divide between the urban and rural areas
- Personalized learning experiences are facilitated through adaptive learning technology, catering to individual student needs and preferences.
- Games and gamification techniques are employed to make learning more enjoyable and interactive, fostering increased student engagement and motivation.
- Integration of IoT devices into educational settings creates a more interconnected and efficient learning environment by embedding technology into everyday objects.
- Dedicated maker spaces provide students with exposure to leading-edge technological solutions and tools, enabling them to explore and innovate through hands-on projects.
- Flipped classroom models invert traditional teaching approaches, placing students at the forefront of their learning journey.
- Wearable devices allow educators to monitor student engagement and progress in real-time, facilitating personalized support and interventions.
- Three-dimensional printing technology empowers students to materialize their ideas and concepts, fostering creativity and tangible learning outcomes.
- Artificial Intelligence (AI) applications in education personalize learning experiences and streamline administrative tasks, optimizing efficiency and effectiveness.
- Integration of mixed reality technologies combines virtual and physical learning environments, offering immersive and interactive educational experiences.
- The introduction of blockchain technology enhances the security and transparency of student records, ensuring integrity and authenticity in educational documentation.

3. Methods

The principal aim of this research is to conduct an in-depth quality evaluation, delineating the current strategic landscape of Information and Communication Technology (ICT) sectors across Saudi Arabia, while also mapping strategies towards achieving sustainable development in the long term. A key focus of this study is to highlight critical driving affecting the quality of reforms in higher education and to ascertain the relative importance of these factors based on their priority. The study involves the identification and classification of various components within the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis framework, to elucidate the complexity of these elements in facilitating the fulfillment of sustainable development goals. This analysis would encompass a qualitative assessment of key factors influencing the quality of higher education reforms in Saudi Arabia, with a focus on prioritizing these factors based on their significance.

4. Econometric Analysis

4.1 Data and Description of the Variables

The data for Saudi Arabia for the duration from 1990 to 2022 are gathered from the World Bank, IMF, and UNDESA. We have experienced the problem of missing data during the data collection process, to solve this issue, we extrapolate the missing data in Stata. This study employed the education index (EDI) as a dependent variable, a composite of the Human Development Index (HDI), employed as a proxy to examine the degree of school enrollment and literacy rate in the studied countries (Kim et al., 2008). ICT-related components including, mobile cellular penetration (MCS), individuals using the internet (IUI), and fixed telephone subscribers (FTS) are assessed as the independent variables. The past research of Andres et al. (2017) and Farooqi et al. (2020) also explored the influence of these ICT-related components on the different composites of HDI in the region of sub-Sahara Africa and different developing countries, respectively. Furthermore, the descriptive statistics of the observed variables are demonstrated in Table 1. The education index in Saudi Arabia ranges from 0.4 to 0.86.

Table 1: Descriptive Statistics

Variables	Mean	Std. Deviation	Min	Max
EDI	.6312813	.1244869	.452	.865
FTS	13.34857	3.017394	7.710205	18.60338
MCS	77.14226	69.16126	.0847484	179.0989
IUI	41.48728	37.36407	.0109561	100

4.2 Model Specification

To determine the impact of information technology in promoting the quality of education in the context of Saudi Arabia, the econometric model is specified as;

$$lnEDI\mathrm{t} = \alpha 0 + \beta 1\ lnFTS\mathrm{t} + \beta 2\ lnMCB\mathrm{t} + \beta 3\ lnIUI\mathrm{t} + \varepsilon\mathrm{t} \qquad (1)$$

Where lnEDI indicates the education index, lnFTS implies the fixed telephone subscribers and lnMCS and lnIUI denote the cellular mobile subscribers and individuals using the internet, respectively. εt is the stochastic error.

To investigate the long-run relationship among the series when they have unit roots at level, the selection between the Vector Error Correction model (VECM) and the Vector Autoregressive model (VAR) is required. When all the variables achieve stationarity at the first difference I(1) but are not co-integrated, then the VAR model is the most suitable while, if they have co-integration, the VECM model is the appropriate model to be applied. Consequently, the stationary test is essential to evaluate the stationarity condition of each series before applying the VECM or VAR model. Thus, the Augmented Dickey-Fuller (ADF) unit root test is employed to check the stationarity of each variable included in the study in the form of a natural logarithm.

Augmented Dickey-Fuller Test

ADF unit root test is applied to assess the stationarity condition of the variables and the following equation is specified for the unit root test,

$$\Delta y_t = \alpha_0 + \beta_0 t + \delta Y_{t-1} + \sum_{i=1}^{m} \gamma_i \, \Delta Y_{t-i} + \mu_t \qquad (2)$$

Where y signifies the series examined for the unit root test in time t, α_0 is the constant term t is the indicator for time trend, ΔY_{t-I} is the lag difference of the examined series, and μ_t represents the disturbance term. The null hypothesis for the ADF test (H_0): $\delta=0$, implies that if the threshold level of critical value is less than the absolute value of t-statistics, the null hypothesis of series being stationary can be rejected.

Johansen Co-Integration Test

Johansen (1995) introduced a co-integration test to estimate the co-integration among the time series data. If k number of variables integrated at order 1, they might have a k-1 co-integration relationship which is recognized as rank (r). The null hypothesis (r=0) is estimated against the alternative hypothesis (r≤1), estimating the co-integration of rank 1. If the null hypothesis (r=0) is to be rejected, this indicates that no co-integration association exists between the series, further analysis requires a VAR framework to estimate. Whereas, the rejection of the null hypothesis reflects a co-integration association among the variables and can proceed with the VECM model.

The process of Johansen co-integration is based on maximum (λmax) eigenvalues and trace (λtrace) statistics to evaluate the number of co-integrating vectors. For trace statistics, the rejection of H_0 indicates no c-integration association. The estimated trace statistics and maximum eigenvalues can be specified as follows,

$$\lambda_{\text{trace}}\,(r) = -T \sum \ln[1 - \lambda i\,] \qquad (3)$$

$$\lambda_{max}\,(r, r+1) = -T \ln[1 - \lambda r + 1] \qquad (4)$$

Where T denotes the number of observations, λi is the eigenvalues, r+1 is the co-integrating vector. The null hypothesis for trace statistics is r co-integrating vectors against n co-integrating vectors (alternative hypothesis). However, the null hypothesis of maximum eigenvalues estimates r co-integrating vectors against r+1 co-integrating vectors (Hjalmarsson and Österholm, 2007). The decision rule for both co-integrating statistics is if the calculated statistics exceed the critical values, then the null hypothesis can be rejected, which means there is a co-integration association among the variables.

Vector Error Correction Model

The vector error correction model (VECM) is employed to determine the long-run and short-run association among the variables. However, if series are not co-integrated then VECM implies the reduced form of VAR framework. The econometric form of the VECM model with (p-1) is specified below, where p is the lag of endogenous variable with co-integrating rank ≤ r

$$\Delta lnEDI_t = \alpha 1 + \sum_{i=0}^{p} \beta_i \, \Delta lnEDI_{t-i} + \sum_{i=0}^{p} \delta_i \Delta lnFTS_{t-i} + \sum_{i=0}^{p} \theta_i \Delta lnMCS_{t-i} + \sum_{i=0}^{p} \varphi_i \Delta lnIUI_{t-i} + \lambda 1 \, ECT_{t-1} + \mu 1t \qquad (5)$$

$$\Delta lnFTS_t = \alpha 2 + \sum_{i=0}^{p} \beta_i \, \Delta lnEDI_{t-i} + \sum_{i=0}^{p} \delta_i \Delta lnFTS_{t-i} + \sum_{i=0}^{p} \theta_i \Delta lnMCS_{t-i} + \sum_{i=0}^{p} \varphi_i \Delta lnIUI_{t-i} + \lambda 2 \, ECT_{t-1} + \mu 2t \qquad (6)$$

$\Delta lnMCS$t $= \alpha 3 + \sum_{i=0}^{p} \beta$i $\Delta lnEDI$t-i $+ \sum_{i=0}^{p} \delta$i$\Delta lnFTS$t-i $+ \sum_{i=0}^{p} \theta$i$\Delta lnMCS$t-i $+ \sum_{i=0}^{p} \varphi$i$\Delta lnIUI$t-i $+ \lambda 3\ ECT$t-1 $+ \mu 3$t (7)

$\Delta lnIUI$t $= \alpha 4 + \sum_{i=0}^{p} \beta$i $\Delta lnEDI$t-i $+ \sum_{i=0}^{p} \delta$i$\Delta lnFTS$t-i $+ \sum_{i=0}^{p} \theta$i$\Delta lnMCS$t-i $+ \sum_{i=0}^{p} \varphi$i$\Delta lnIUI$t-i $+ \lambda 4\ ECT$t-1 $+ \mu 4$t (8)

Where Δ signifies the difference of the series, μit, i = 1, 2…,4 are disturbance terms that are assumed to be normally distributed. p is the optimal lag length recommended by FPE, AIC, HQIC, and SBIC criteria. λI is the coefficient of adjusted error correction term (ECTt-1). The expected sign of ECT is negative and it is used to examine the long-run causal association and the speed of convergence to long-run equilibrium. ECTt-1 can be specified as,

ECTt-1$= [lnEDI$t-1 $+ \omega lnFTS$t-1$+ \gamma\ lnMCS$t-1$+ \delta\ lnIUI$t- $+ \vartheta]$ (9)

5. Results and Discussion

5.1 SWOT Analysis

Education is the primary resource that drives people's prosperity and is referred to as a "social elevator" (Woolf et al., 2013). As a result, ensuring individuals have equitable access to quality education is critical. Enhancing educational accessibility to the most remote and disadvantaged populations necessitates the comprehensive incorporation of cloud-dispersed technologies, Internet, augmented reality, and AI, in educational systems, with a dual goal in mind (Zhou et al., 2017). To begin, construct an interactive education system that allows the adoption of various educational approaches that adjust to the needs of students and are equipped with intelligent tutoring systems (Palomares et al., 2021). Second, to provide education possibilities for disadvantaged groups, women, and persons with restricted access to on-site physical learning in the least developed countries. On a related point, small and medium-sized businesses should have access to learning tools to engage in the necessary digital self-enhancement to adjust the modification brought about by the present revolution in technology.

A good education is also necessary for developing communities where people are treated equally irrespective of their color, principles, opinions, gender, sexual preferences, and individual or societal position (Noriega, 2020). However, the ultimate value of equality, as stated in international legal codes, should be embodied in the actions of individuals daily. The social aspect of sustainable development includes promoting interpersonal relationships rooted in equality in all its forms. Therefore, the equality framework encompasses targets focused on providing equal access to education are shown in Figure 1.

Strengths	Weaknesses
– Interactive learning tools supported by mobile apps and gamification.	– Low impact of virtual reality in schools.
– AI-based personalization to provide contents adapted to learners' individuals needs.	– More attention needed in adapted and location-based teaching systems to yield equity, efficiency and quality education.
– Immersive learning fosters community-level interaction and resource sharing across disciplines.	– Insufficient training on use of technology and user-computer interaction in education systems.
– User-centered software design favors inclusive education.	– Identifying present and future key competences to ensure lifelong learning.
Opportunities	**Threats**
– Chatbots to promote classroom participation and student engagement.	– Lack of teachers' skills in digital technologies.
– Intelligent tutors scale-up possibilities towards one-to-one education tailored to the individual, and supporting students with special needs.	– Equal access to technologies and AI training is still not a universal right.
– Platforms for sharing contents and ideas empower citizens and drive equality.	– Level of training in AI far below the pace of digital transformation in society.

Figure 1: SWOT Analysis (Education)
Source: Author's Evaluation

5.2 Challenges and Opportunities in ICT Development and Internet Usage in Saudi Arabia

Saudi Arabia, as a prominent oil-exporting nation, encounters significant hurdles in fostering export-oriented ICT service and manufacturing industries. The ICT manufacturing sectors within Saudi Arabia often exhibit limited integration with the broader national economy. Much of the investment in ICT manufacturing originates from external sources instead of domestic capital markets, resulting in constrained local economic benefits. Despite efforts to promote diversification under Vision 2030, the country's heavy reliance on oil revenues has historically diverted attention from nurturing a robust ICT sector for export purposes. Furthermore, while strides have been made to promote ICT development domestically, export-oriented service industries, such as software development and back-office activities, have predominantly thrived in countries with more established ecosystems and skilled workforces. Moreover, Saudi Arabia's economy is deeply entrenched in commodity production, particularly oil, rendering ICT investment less appealing in comparison to developed nations. Consequently, the level of ICT investment as a proportion of national production remains relatively subdued, with the real benefits for national growth likely to materialize over an extended period.

The development agencies are interested in ICTs as they focus on poverty reduction rather than their potential impact on national or corporate economic performance. Despite the

ICT industry's influence on national economic performance, ICT adoption can advance mainstream development targets (health and education fields). The nexus between development goals and economic growth is twofold: growth tends to flourish in healthier, more educated societies, where people and societies are equipped with the skills and abilities to realize their full potential and create new business prospects. However, achieving these development objectives tends to be more feasible in an environment of economic growth. ICTs may therefore help improve mainstream social development and national economic performance, a dual opportunity that policymakers in ICT and development for a developed nation should understand better.
With the advent of the internet in the 1990s, information and communication technology (ICT) has emerged as a powerful instrument for closing the divide between the developed and developing worlds by omitting specific phases of industrial progress and transitioning swiftly into the information economy. When adopted correctly and for the proper reasons, ICT may have a significant influence on accomplishing certain social and economic development goals.
Between 2017 and 2020, the number of internet users (in millions) in Saudi Arabia (Figure 2). The number of internet users is increasing over time. The provided data presents the number of internet users (in millions) in Saudi Arabia from 2017 to 2020. In 2017, Saudi Arabia had 31.80 million users. However, over the subsequent years, the kingdom experienced growth in internet usage. In 2020, Saudi Arabia saw a more notable increase to 35.50 million users.

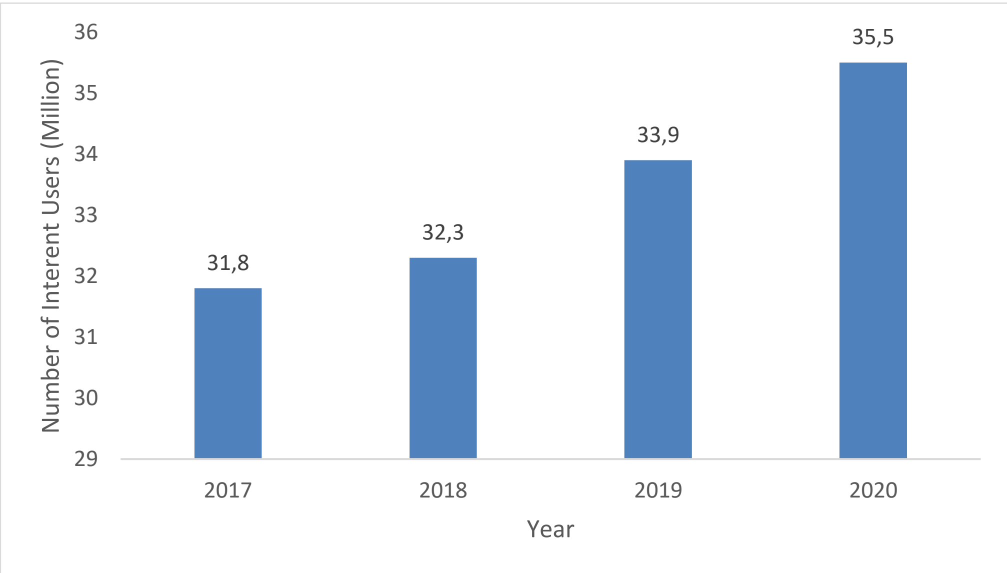

Figure 2: Internet users in Saudi Arabia

Figure 3 shows the number of mobile subscribers (in millions) in Saudi Arabia from 2014 to 2021. In 2014, Saudi Arabia had 52.74 million subscribers. Over the subsequent years, Saudi Arabia experienced growth in mobile subscriptions. By 2015, Saudi Arabia saw a slight increase to 52.8 million subscribers. However, from 2016 onwards, there was a noticeable decline in mobile subscribers in Saudi Arabia, dropping to 47.93 million in 2016 and further declining to 40.21 million in 2017. From 2018 onwards, the trend shifted again. Saudi Arabia's mobile subscriber count began to rise, reaching 41.31 million in 2018 and peaking at 45.43 million in 2021. The data highlights the evolving landscape of mobile telecommunications in Saudi Arabia over the years, with fluctuations in subscriber numbers.

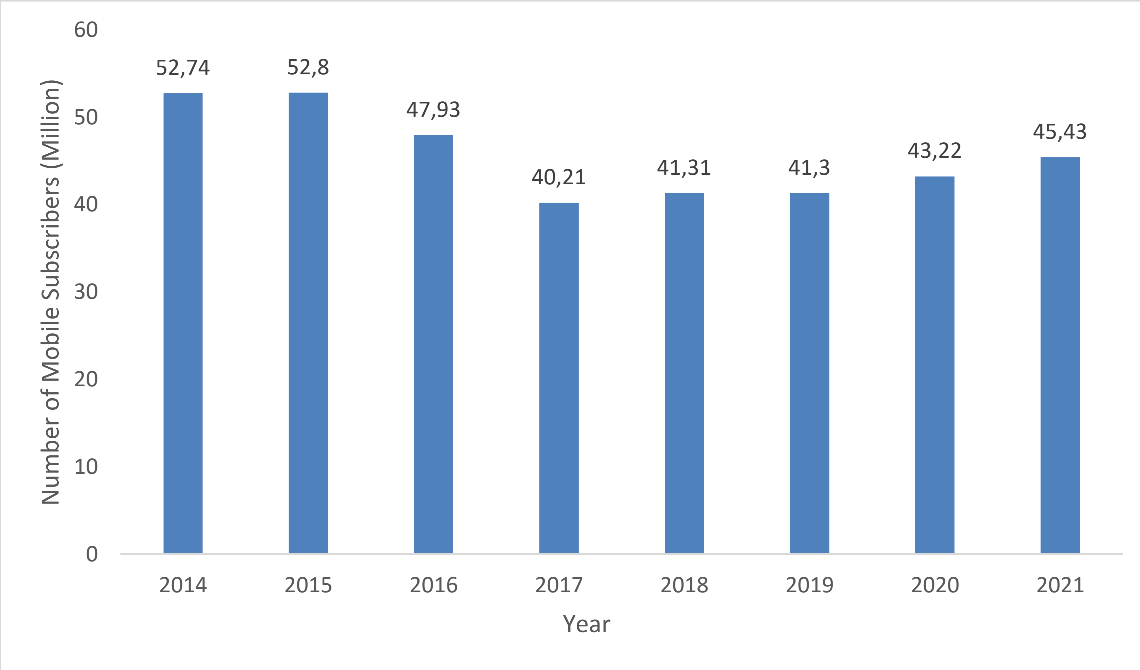

Figure 3: Mobile subscribers in Saudi Arabia

5.3 Empirical Findings

To estimate the association between information communication and technology and the quality of education in Saudi Arabia, this study used the VECM approach. As discussed in the methods of econometric analysis, to avoid unbiased and unreliable results, first we have to check the multicollinearity and stationarity in the model.

The correlation among the variables is presented through the correlation matrix in Table 2. It is observed that all variables are positively correlated thereby it can lead to the multicollinearity problem in the model. To examine the presence of multicollinearity, we employed a variance inflation factor (VIF) test. If the value of VIF is less than 10, it could be said that there is no multicollinearity issue. Therefore, it can be noticed in Table 2, that all variables have a VIF value of less than 10 thus our model does not experience a problem of multicollinearity.

Table 2. Correlation Matrix

	lnEDI	lnFT	lnMC	lnIUT	VIF
lnEDI	1.0000				
lnFT	0.7252	1.0000			4.35
lnMC	0.8887	0.8773	1.0000		4.53

lnIUT	0.5528	0.4186	0.4552	1.0000	1.26
				Mean VIF	3.38

To determine the causal association between the education and ICT component in Saudi Arabia, we first need to test the stationarity of all series to examine the order of integration of each variable. Table 3 presents the outcomes of the Augmented Dickey-Fuller (ADF) test. It can be seen in the table that none of the variables is stationary at level, indicating an acceptance of the null hypothesis (all variables are non-stationary) as their p-values exceed 0.05. After the first differencing, all variables are stationary. Thus, all variables are integrated into order 1.

Table 3. ADF Unit Root Test

Variables	Level		First Difference	
	Constant	Trend	Constant	Trend
LnEDI	-1.927	-0.459	-3.558 ***	-3.446**
LnFT	-1.325	-1.976	-3.623**	-3.586**
LnMC	-2.137	-0.657	-2.746*	-3.617**
LnIUT	-1.701	-2.785	-3.723***	-3.745***

*Note: ***, **, and * denotes significance level at 1%, 5%, and 10%.*

Since the stationarity test of the variables enables us to proceed further. However, this needs a pre-estimation of number of lags. Table 3 illustrates the findings of optimal lag selection. Based on the FPE, AIC, HQIC, and SBIC criteria, it is suggested that an optimal lag length is four.

Table 4. Lag selection

Lags	LL	LR	FPE	AIC	HQIC	SBIC
0	-66.0244		.001471	4.82927	4.88833	5.01786
1	40.4703	212.99	2.9e-06	-1.41174	-1.11642	-.468782
2	78.637	76.334	6.8e-07	-2.94049	-2.4089	-1.24315
3	106.822	56.37	3.5e-07	-3.78083	-3.01299	-1.32913
4	140.627	67.609*	1.6e-07*	-5.00874*	-4.00464*	-1.80267*

As all the series are integrated at order 1 or I (1) thus there may be a co-integration among them if some linear combination of series exists. Table 5 represents the findings of the Johansen co-integration test (Johansen, 1995). Based on trace statistics and maximum eigenvalues, the null hypothesis of no co-integration is rejected. The findings based on trace and maximum statistics recommend that there is at least one co-integrating equation in the series. Therefore, Johansen's co-integration test suggested that variables are co-integrated in the long run. Therefore, this study would employ the VECM model for both short-run and long-run dynamics.

Table 5. Johansen Co-Integration Test

Hypothesized No. of Co-	Eigenvalues	Trace statistics	Max statistics	95% Critical	95% Critical value for Maximum

integrating equation				value for trace test	Eigenvalue test
At most 1	0.81459	59.7282	32.2738	29.68	20.97
At most 2	0.67139	27.4544	21.5816	15.41	14.07
At most 3	0.52488	5.8728	5.8728	3.76	3.76
At most 4	0.18332				

The short-run association between the education and ICT variables is reported in Table 6. it is observed that one lag period of education index positively and significantly causes the current education index. However, two lag periods of the education index negatively but significantly causes the current education index. On the other hand, one and two lag periods of fixed telephone subscribers (FTS) have significant negative and positive causal relationships with the current education index, respectively. Moreover, mobile cellular subscribers (MCS) have negatively and significantly caused the current education index. While individuals using the internet (IUI) have no causal relationship with the current education index. In addition, it is also observed that R-squared (coefficient of determination) is 0.90, indicating a 90% of variation in the dependent variable is explained by the independent variable. Error correction term (ECT) also is significant and negative, indicating the convergence of variables towards long-run equilibrium. This also signifies that ICT components including fixed telephone subscribers, mobile cellular subscribers, and individuals using the internet in Saudi Arabia are essential variables in determining the extent of education in the long run. ECT equation can be written as,

$$ECT_{t-1} = [1.000 lnEDI_{t-1} - 0.394 lnFTS_{t-1} + 0.091 lnMCS_{t-1} - 0.0099 lnIUI_{t-} + 0.1802]$$

Table 6. Short-run Estimation of VECM Model

Variables	Coefficient	Standard Error	P- value
Δ(lnEDI) (-1)	1.167	0.284	0.000
Δ(lnEDI) (-2)	-2.655	0.4313	0.000
Δ(lnFTS) (-1)	-0.1253	0.0602	0.037
Δ (lnFTS) (-2)	0.2132	0.0637	0.001
Δ(lnMCS) (-1)	-0.0473	0.0202	0.020
Δ(lnMCS)(-2)	-0.0029	0.0108	0.784
Δ(lnIUI) (-1)	-0.00081	0.0025	0.750
Δ(lnIUI) (-2)	-0.0087	0.0054	0.107
_cons	0.0846	0.0143	0.000
ECT	-0.280	0.059	0.000
R-squared	0.9081		
Sum square residual	.020428		
chi2	197.5641		
P>chi2	0.0000		

The findings of the long-run estimation of the VECM model are demonstrated in Table 7. It can be noticed that fixed telephone subscribers negatively but significantly affected the education index in the long run. This means that a 1% rise in FTS will lead to a decrease education index by 39%. Similarly, individuals using the internet also have a negative but insignificant influence on the education index. However, mobile cellular subscribers positively and significantly affect the education index. This underscores that a 1% increase in MCS will increase the education index by 9.8%.

Table 7. Long-run Estimation of the VECM Model

Variables	Coefficient	Standard Error	P- value
lnFTS	.3945647	.1907466	0.039
lnMCS	-.0987341	.0132675	0.000
lnIUI	.0099612	.0132403	0.452
_cons	-.1802872	.	.

5.4 Diagnostic Test for VECM Model

To assess the robustness of the studied model, a diagnostic test is conducted. Table 8 summarizes that the model does not observe the problem of serial correlation across the error term since the Lagrange multiplier test failed to reject the null hypothesis of no serial correlation up to lag 2 (p-value= 0.059, insignificant at 5% level of significance).

Table 8. Lagrange Multiplier (LM) test for Serial Correlation

Lags	chi2	Prob > chi2
1	25.6939	0.05849
2	25.6477	0.05919

The outcomes of the Jarque-Bera test are reported in Table 9. It is witnessed that the joint value of probability for the Jarque-Bera test is greater than 0.05, indicating that series are normally distributed.

Table 9. Test for normality

Equation	chi2	Prob > chi2
Δ(lnEDI)	0.107	0.94805
Δ(lnFTS)	1.575	0.45505
Δ(lnMCS)	0.237	0.88839
Δ(lnIUI)	0.783	0.56892
Joint	1.658	0.36921

To examine the number of co-integrating equations that are properly recognized, the study checks the stability condition of the specified VECM framework. Thus, the outcomes of Table 10 show that the modulus of each eigenvalue is less than 1, suggesting the stability of the VECM model.

Table 10. Stability Condition for VECM Estimates

Eigenvalue	Modulus
1	1
1	1
1	1
.8087549 + .2119194i	.836059
.8087549 - .2119194i	.836059

.3174856 + .7213545i	.78813
.3174856 - .7213545i	.78813
-.703387 + .05772104i	.705751
-.703387 - .05772104i	.705751
.4191057 + .4850495i	.641032
.4191057 - .4850495i	.641032
-.1337128 + .5764114i	.591717
-.1337128 - .5764114i	.591717
-.3819917	.381992

6. Discussion

Based on the empirical estimation, we have found short-run as well as long-run associations between the education index and components of information and communication technology in Saudi Arabia during the period 1990-2022. It is observed that in both long-run and short-run FTS negatively and significantly affects the education index. However, these results are not consistent with the research of Acheampong et al. (2022), which advocated the positive impact of FTS on the human development index. However, Farooqi et al. (2022) also found a positive and significant of FTS on the education index across low-income countries. Consequently, mobile phone penetration positively and significantly impacts the education index in Saudi Arabia. The study of Ngwenyama et al. (2006) revealed a positive impact of the ICT component on the education index. Similarly, Acheampong et al. (2022) also underscored a favorable and significant impact of mobile penetration on the composite of the human development index. Similarly, Asongu and Nwachukwu (2017) also highlighted the positive influence of mobile penetration on the education level in the sub-Sahara African region. On the other hand, we have found a negative but insignificant influence of individuals using the internet on the education index in both the long and short run. However, Farooqi et al. (2022) and Asongu and Nwachukwu (2017) highlighted the significant impact of individuals using the Internet on education across low-income and upper-income countries.

It is important to highlight that gender disparities in ICT adoption present a significant hurdle in Saudi Arabia, where a substantial portion of the female population lacks familiarity with contemporary ICT technologies. Efforts to enhance ICT literacy among women are crucial for promoting gender equality and empowering women in the digital realm. Additionally, the rural-urban digital divide poses a formidable challenge, with rural areas often lacking adequate ICT infrastructure and connectivity. As the majority of Saudi Arabia's population resides in rural regions, bridging this gap is imperative for fostering inclusive development and ensuring equitable access to ICT resources.

Moreover, while modern telecommunications technology holds immense potential, particularly in sectors such as education, its transformative impact is constrained by limitations in raising rates and productivity across other industries. Strategic interventions are needed to harness the full potential of telecommunications technology and leverage it as a catalyst for broader economic development in Saudi Arabia.

7. Recommendations

In Saudi Arabia, one of the foremost challenges confronting the ICT sector is the effective implementation of E-Government initiatives across diverse government departments to reinforce the rule of law. Although information technology stands as a pivotal tool in this endeavor, its advancement is impeded by entrenched issues of corruption within the country. The prospect of implementing E-Governance is met with apprehension among certain segments of society, particularly those who perceive it as a threat to their illicit sources of income. Consequently, the government must navigate these complexities and ensure that E-Government initiatives are executed in a manner that upholds national interests and benefits all citizens.

Considering the complexities of ICT development, the study presents recommendations for both developed and developing nations. Developed nations should prioritize continued investment in innovation to maintain their competitive edge, alongside efforts to address remaining disparities in digital access and bolster cybersecurity measures to safeguard critical infrastructure. Conversely, developing countries require a concerted focus on infrastructure development to improve ICT access, coupled with initiatives to enhance digital literacy and education, particularly among marginalized populations. Embracing sustainable ICT growth and fostering international collaboration can further accelerate progress in both contexts, ensuring that the benefits of ICT are harnessed for inclusive economic and social development. By tailoring strategies to their unique needs and challenges, developed and developing countries alike can pave the way for a more equitable and prosperous digital future.

8. Conclusion

In conclusion, the discussions underscore the critical importance of Information and Communication Technology (ICT) in shaping societies, economies, and educational systems worldwide. Developing countries like Saudi Arabia face challenges related to infrastructure development, digital inclusion, and economic diversification. Moreover, the empirical analysis also revealed that ICT played an important in improving the education index as Mobile cellular penetration has a significant and positive long-run association with the education index in Saudi Arabia. Investments in ICT infrastructure, promotion of digital literacy, and fostering innovation, and collaboration, alongside sustainable ICT growth, emerge as crucial pillars for progress in Saudi Arabia. By implementing these recommendations, the country can harness the transformative power of ICT to drive inclusive economic growth, enhance social well-being, and achieve sustainable development goals. Moreover, international collaboration and knowledge sharing contribute significantly to nurturing global partnerships and accelerating ICT development efforts. Ultimately, by prioritizing these strategies and working collaboratively, nations can leverage the full potential of ICT to construct a more prosperous, equitable, and digitally-enabled future for all.

9. Study Limitations and Future Direction

This study has some limitations to acknowledge. Firstly, this study didn’t include the effect of external drivers such as government policies on the adoption of ICT as these policies contribute significantly in determining the ICT setting in education. Future studies could analyze the impact of government policies on the implementation of ICT in educational settings. This could offer an in-depth analysis of how ICT implementation can improve educational consequences. In addition, closing the digital gap is important to ensure that ICT integration improves the student experiences, irrespective of their location. Future studies could examine strategies to enhance ICT infrastructure in rural areas to promote more inclusive dissemination of educational resources. This study incorporates growth in the use of mobile and internet but didn't mention concerns related to cyberattacks. However, over-dependence on ICT can lead to concerns related to data privacy and security in educational settings. Future studies could integrate the threats related to technology-enabled education such as cyber threats, data privacy, and security concerns. Furthermore, this research mentions the favorable influence of mobile penetration on education but doesn't discuss the possible disadvantages, such as excessive use of cellular phones can affect students' mental health and their academic performance. Future studies could analyze the procedures to integrate conventional learning with mobile technology to ensure the academic development of students. This could provide more valuable insights into the role of ICT in shaping the education framework. This study acknowledged potential biases due to missing values in data although this limitation was managed through extrapolation still it may affect the generalizability and accuracy of the study outcome.

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Data Availability Statement

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Ethical Approval

This research is based on publicly available secondary data and does not contain any studies with human participants performed by any of the authors.

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