Unlocking the Synergy: ICT, Global Trade, and Growth in the GCC Region - A Panel-Causality Analysis

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Abstracts: This study investigates the intricate relationship between Information and Communication Technology (ICT), global trade, and economic growth in the Gulf Cooperation Council (GCC) region over the period 1990–2022. The study Utilize a panel data framework covering the GCC member states over a significant time span, and employing an advanced econometric technique to assess the causal and cointegrated relationships among these key variables. Three tests, [1], [2], [2] Cointegration tests are applied to check for Cointegration. Additionally, fully modified least square (FMOLS) and dynamic ordinary least square (DOLS) will be used to test the magnitude of the long relationship among variables. The analysis integrates a comprehensive dataset that includes ICT indicators, trade flows, and macroeconomic variables, allowing for a robust examination of the synergy among these critical elements. The results reveal multifaceted relationships within the GCC context. While ICT is found to have a positive and significant impact on global trade and economic growth, the study also identifies bidirectional causality between ICT and global trade, indicating a reinforcing loop. Furthermore, evidence suggests that global trade plays a pivotal role in enhancing ICT diffusion within the region. The findings of this paper have several ramifications. First, they highlight the necessity for GCC governments to give priority to digitization and ICT infrastructure development activities in order to promote international commerce and economic diversification. Second, Policymakers should also consider crafting trade policies that facilitate the exchange of ICT-related goods and services, further fostering economic growth.

Keywords: ICT, Global Trade, Economic Growth, Panel Data, Causality, GCC.

1. INTRODUCTION

The dynamic interaction between information and communication technology (ICT), global trade, and economic growth has arisen as a crucial research field in a time of increasing globalization and technological advancement. Due to its strategic geographic location, abundant natural resource endowments, and rising desire to diversify its economic base, the Gulf Cooperation Council (GCC) area has attracted a lot of attention in this context. In addition to being a prominent player in the world oil market, the GCC, which consists of six member nations (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates), is also becoming a more significant hub for commerce, banking, and investment. The region's economic environment has seen a significant transition over the last few decades, highlighted by a purposeful shift away from an economy dependent on oil toward one supported by significant investments in ICT infrastructure. The growth in foreign trade in the contemporary era attributed mainly to the technological developments and digitalization. In the past 15 years, the total value of global digitally deliverable services (DDS) has almost tripled since 2005 from US$ 1.2 trillion in 2005 to US$ 3.2 trillion in 2019. During the period, the share of DDS in all services trade rose from 45 per cent to 52 percent. [4] Digitalization on the other hand has been expanded over the last two decades due to the advent of Information and Communication Technologies (ICT). Digitalization stimulated economic growth through transforming world economies and seem to offer a vast potential to enhance the productivity and the proper use resources. In this context, the information economy report of [5] stated that, “the digital economy [6] is expanding in several ways. Global production of ICT goods and services now amounts to an estimated 6.5 per cent of global gross domestic product (GDP), and some 100 million people are employed in the ICT services sector alone. Exports of ICT services grew by 40 per cent between 2010 and 2015. The digital economies of GCC countries have grown rapidly over the past decade, creating an opportunity to catch up with digital [7]. The GCC posted steady advancements in digital development —

its DEI score grew the fastest compared to any other part of the world. The ICT Index (DEI) has been developed in order to provide an assessment of the digital maturity of 109 countries throughout the world in the decade up to 2020. The index is based on five pillars – foundations (comprising investment, connectivity and regulation), talent, innovation, adoption, and local production. The main objectives of this paper are to study the effect of ICT on global trade and economic growth of a panel of six gulf countries during the period 1990–2022 and to produce new evidence on the economic growth and these variables. Therefore, a test of the relationship between economic growth and ICT for these countries could reveal important information on this issue. Secondly, very few studies were conducted to test the impact of ICT and global trade on economic growth of GCC. The paper is organized into five sections. 2. An overview of ICT and Trade in the GCC Region discussed section 2. A brief literature review is discussed section 3. Section 4 describes the model specification and data Section 5 presents the analysis and discussion. Section 6 concludes the paper and section 7provides some policy based on the empirical findings. Information and Communication Technology (ICT) has played a significant role in the development and modernization of the Gulf Cooperation Council (GCC) region, which includes six member states: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE). This region has witnessed remarkable growth and transformation in the ICT sector over the past few decades. The World Economic Forum emphasized the distinctive qualities of the GCC nations, which provide a variety of options for utilizing cutting-edge technical solutions to generate opportunities. With an eye toward sustainable development and equitable growth, the deployment of 5G and related use cases, such as education, health, governance, and smart cities, can help offset several regional and local difficulties, including natural resource management and economic diversification. The growth of ICT in the GCC area has boosted productivity, strengthened the digital economy, and established effective channels for direct access to government e-services. In reality, governments throughout the GCC have made digital transformation a priority, placing it at the center of their goals for social and economic growth and a crucial part of each of their own Vision programs. According to the GCC E-Performance Index, the UAE had real progress, earning an average score of 66.22. Saudi Arabia came in second with a score of 59.26, while Qatar came in third with a score of 57.63. The average ratings for Oman, Bahrain, and Kuwait were 54.02, 53.43, and 51.36, respectively. Additionally, the GGC make great effort towards developing the ICT sector through the following: Infrastructure Development: The GCC nations have made significant investments in creating a strong ICT infrastructure, which includes data centers, high-speed internet access, and cutting-edge telecommunications networks. This has opened the door for innovation and digital transformation in several industries. Smart Cities and Urban Development: To improve the quality of life for citizens, several GCC cities are implementing smart city programs. IoT sensor deployment, smart transportation systems, and integrated public services are a few of these endeavors. Mobile Penetration: The GCC has embraced mobile technology for communication, payments, and services, and the region has one of the highest rates of mobile penetration in the world. Mobile apps and services are extensively utilized for everything from banking to government services. E-Government Services: The GCC's governments have undertaken extensive e-government projects to give citizens and residents internet access to a range of services, such as visa applications, utility bill payments, and company registration. Financial Technology (FinTech): The GCC area has experienced rapid expansion in the FinTech industry, with an emphasis on mobile banking, blockchain technology, and digital payment systems. Additionally, governments have promoted innovation by creating regulatory sandboxes. Blockchain and Cryptocurrency: Interest in blockchain technology and cryptocurrencies has been shown by certain GCC nations. They are looking at the possible advantages and legal frameworks of these new technologies. Startups and Innovation hubs: A number of GCC cities, including Dubai and Riyadh, have created startup ecosystems and innovation centers to promote entrepreneurship and draw in tech talent. Even though the GCC area has made enormous strides in ICT, there are still many obstacles to overcome. These include the need for stronger data privacy and cybersecurity measures, bridging the digital gap, and making sure that the advantages of ICT are available to all facets of society. However, the GCC region's dedication to innovation and digitization continues to fuel economic development and diversity. International trade on the other hand, plays a significant role in the economies of the Gulf countries, The large oil and gas deposits of the GCC nations are well-known, and the energy industry has traditionally been a major driver of trade. However, exports of energy resources serve as the primary economic engine for the economies of the Gulf states. To maintain long-term economic viability, these countries are actively seeking to diversify their economies and increase trade relations with non-oil countries. (Figure 1). They are important participants in the world of international trade thanks to their strategic geographic position and infrastructural investments.

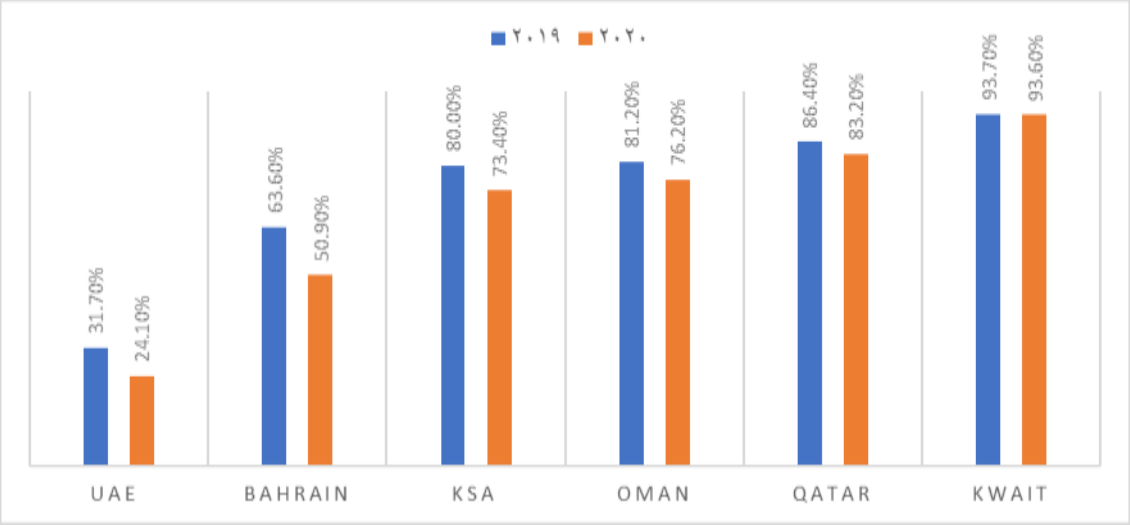

Figure 1. Percentage of Non-Oil Exports from Total Exports in GCC (%).

According to the theoretical literature on economic growth and trade openness shows that trade openness is a very important factor for improving economic growth. In fact, trade openness is seen as one of the fundamental determinants for refining domestic investment and for boosting productivity and growth. Studies that have shown that trade openness has a significant positive impact on economic growth include [8], [9], [10], [11] [12], [13] [14]. The concept of the "ICT" is originated in the last decade of the 20th century. It was first proposed [15]. The Organization for Economic Co-operation and Development (OECD) described the concept of the ICT as "the digital transformation of economic and social development" and considered all traditional industries in the process of digitization and networking as part of the ICT. In this case, digital technologies mean the Internet, mobile phones and all other means of collection, storage, analysis of information and exchange in digital form [16]. The ICT mainly based on ICT helps to increase capital and labor productivity and to obtain goods and services at lower prices (13). For example, [17] have stated the influence of ICT on productivity. According to the authors ICT influences productivity through a number of ways. First, it can affect productivity through its forward and backward linkages with the rest of the economy. Second, since the non-ICT sector uses ICT goods and services in its production processes it can improve its productivity. Third, market processes will be improved leading to productivity improvement. Forth, because of its network externalities features it can be more productive the more people use it. Finally, ICT catalyzes the creation of new knowledge that enhances productivity. They concluded that the use of ICT in the final output sector can lead to improvement in growth performance.[18] explained that how telecommunications infrastructure affects economic growth. They use a sample from 21 OECD countries over a 20-year period to estimate a micromodel for telecommunication investment with a macro production function [19]. They find evidence of a significant positive causal link, especially when a critical mass of telecommunications infrastructure is present. Employed the robust two-step system GMM to empirically analyzed the impact of mobile phone and the Internet on per capita income of Sub-Saharan Africa (SSA) for the period of 2006–2015 using a panel data of 40 countries. Their Results showed that growth in mobile phone penetration has contributed significantly to the GDP per capita of the region after controlling for a number of other variables. A 10% increase in mobile phone penetration results in a 1.2% change in GDP per capita. Therefore, improving access to mobile phones will play a critical role in reducing the poverty level of the region through raising the per capita income of the population. [20] Carried out an in-depth study of the ICT in the US and China and confirmed their growing economic influence and dominance. The underlying reasons for their leadership in the ICT were defined as the growing investment in research and development (R&D), increased attention to digital innovation and human resources development, the dynamism of the information and communication technology (ICT) sector, possible synergies between the development of personal electronics and online markets, and powerful internet 426 Brazilian Journal of Political Economy 42 (2), 2022 • pp. 424-441 infrastructure. All this together was declared to affect the rates of

economic growth in both countries positively. [21] Focused on reviewing the development of African economies and the impact digital transformation causes on them. For this, they compared business changes occurring in Sub-Saharan Africa with those in OECD by analyzing an 11-year panel dataset (from 2006 to 2016) for 41 countries of Sub-Saharan Africa and 33 OECD member states. Their findings allowed the conclusion about a positive contribution of digitalization to economic growth in both groups of countries, regardless of their development levels. [22] Analyzes the impacts of information and communications technology (ICT) on global trade between Turkey and its trading partners. Using an extended panel gravity model framework, it examines the effects of four ICT indices on Turkish bilateral exports and imports with static and dynamic panel data models for the period 2000–2014. The sample includes 35 countries that import Turkish goods and 34 countries that export goods to Turkey. The results indicate that ICT has positive and significant impacts on both Turkish import and export volumes. [23] Studied the effect of the Internet on global trade. They find that the Internet stimulates trade. By employing time-series and cross-section regressions their results suggest that a 10-percentage point increase in the growth of web hosts in a country leads to about a 0.2 percentage point increase in export growth. For the average country in our sample, the Internet contributed to about a 1-percentage point increase in annual export growth from 1997 to 1999. [24] Estimates the effect of the Internet on promoting global trade. He studies the effect of the Internet on trade by augmenting the gravity equation with the Internet. The empirical results show that a 10% increase in the Internet users increases global trade by 0.2%–0.4%.[25] Analyzed how information and communication technology (ICT) influences global trade volume, and it undertook a comparative analysis of BRICS countries using panel data from the 2000 to 2016 period. The findings showed that (1) the effect of ICT was more positive on exports than imports, (2) the higher the ICT levels in the value chain were, the less effective they simultaneously were on both exports and imports, (3) the effect of ICT levels on trade increased over time, and (4) ICT improvement levels have more positive effects on trade in labor-intensive countries than on resources-intensives BRICS countries. [26] Evaluates the impact of information and communication technology (ICT) on economic growth in Africa based on a sample of 54 countries from 2005 to 2015. The sample is further divided along five sub-regions and the outcomes measured by estimating pooled ordinary least squares, random and fixed effects and GMM models. The ICT indicators are individuals using the internet, mobile subscribers and fixed telephone subscribers with trade openness and inflation rate as control variables. Findings, among others, reveal that ICT development has a statistically significant positive relationship with economic growth. [27] In his paper employs dynamics and static panel data approach within a framework of growth model and apply them to the economy of OIC countries over the time period of 1990-2014. The estimates reveal a significant impact of investments in ICT on economic growth in the countries considered. The policy implication of this paper is that the OIC countries should design specific policies for promoting investment in ICT. [28] Investigate how information and communications technology (ICT) infrastructure impacts on intra-African trade, taking into account other relevant factors that also influence trade such as Institutional Quality and Educational Attainment. Archival data about Telecommunications Infrastructure (a key indicator of ICT infrastructure), Institutional Quality and Educational Attainment and Trade Flows (Export and Import) from 28 African countries were used as empirical evidence. The research employed structural equation modeling with partial least squares to analyze data. The empirical analysis shows that the telecommunications Infrastructure has a major impact on intra-African trade. Interacting factors such as Institutional Quality and Educational Attainment also play a role in influencing intra-African trade. [29] In his study tries to assess the impact of telecommunications penetration on peoples' living standards in Africa through their impact on per capita income growth. [30] Endogenous growth model is employed to estimate the impact of mobile, fixed telephone main lines and the use of the Internet on per capita income in a cross-country analysis covering 49 countries in Africa. The overall results indicate that the telephone main lines and mobile telephony have a significant impact on the people's living standards in Africa, while Internet usage does not have a significant contribution towards economic growth. [31] Estimate the effect of broadband infrastructure, which enables high-speed internet, on economic growth in the panel of OECD countries in 1996–2007. Instrumental variable model derives its non-linear first stage from a logistic diffusion model where pre-existing voice telephony and cable TV networks predicts maximum broadband penetration. They find that a 10-percentage point increase in broadband penetration raised annual per capita growth by 0.9–1.5 percentage points. [32] Using data on Indian states during 2001–2012, the paper analyses the impact of mobile telephony on economic growth. Using advanced panel data techniques, the evidence suggests that mobile telephony exerts a positive and statistically significant impact on growth. The magnitude of the response differs across states with high and low mobile penetration. Additionally, mobile telephony is observed to exert a significant impact on financial inclusion and

especially on the loan behavior. Moreover, over the past 3 decades, the usage of ICT led to develop energy efficiency and productivity in various sectors in developing economies [33]. [34] Using cross-country panel data, we found evidence that the Internet plays a positive and significant role in economic growth after investment ratio, government consumption ratio, and inflation were used as control variables in the growth equation.

2. MATERIEL AND METHODS

2.1. Model Specification and Data

The Solow neoclassical production model is used to analyze the impact of ICT on economic growth via global trade [35] The empirical model, which is based on the conventional Cobb-Douglas production function, is similar to the neoclassical growth model:

$$Y_t = A_t\, Kt^{\alpha}\, Lt^{\beta} \qquad (1)$$

Here, Yt denotes the output growth (in our case, economic growth) of the GCC economy at time t, At is the technological growth, while Kt and Lt represent physical capital and labor respectively. The constants α and β measure the share of physical and labor on aggregate production. To test our model via Cobb-Douglas production function, global trade variable is augmented in the model beside human capital, physical capital, and technological progress. Therefore, equation (1) becomes:

$$Yt = At\, Kt^{\alpha}\, Lt^{\beta}\, Tt^{\delta} \qquad (2)$$

After taking the natural logs of both sides of equation (2), the following equation is obtained:

$$\ln Yit = c + \alpha \ln K_{it} + \beta \ln L_{it} + \delta\, \ln T_{it} + £\ln IC_{it} + \gamma\, \ln CONT_t + \varepsilon_t \qquad (3)$$

Adding the interaction term, to test the joint effect of ICT and global trade on economic growth we arrive at the following equation:

$$\ln Y_{it} = c + \alpha \ln K_{it} + \beta \ln L_{it} + \delta\, \ln T_{it} + £\ln IC_{it} + \pi(\ln T_{it} * \ln IC_{it}) + \gamma\, \ln\, CONT_{it} + \varepsilon_t \qquad (4)$$

Where per capita GDP (constant 2005 US$), denoted as lnYit, is a dependent variable. $\ln L_{it}$, represents the natural logarithm of human capital; index, $\ln k_{it}$ denotes the natural logarithm of capital stocks $\ln T_{it}$, denotes the natural logarithm of global trade; $(\ln T_t * \ln IC_t)$ is the multiplicative interaction term between global trade and ICT index, IC_{it} designates the vector of the natural logarithm of the ICT variables); $CONT_{it}$, denotes the vector of controls variables in natural logarithms. Where, c is the intercept, α, β, δ, £, π and γ are the regression coefficients, and ε_t. is the error term. The study used annual data over the period of 1990-2022. Most of the data were extracted from the World Bank (2022) online databases, except for the human capital and capital stock; variables which are extracted from the Penn World Table version 10.0. All variables have been transformed into natural logarithms (ln) to help mobilize stationarity. All variable definitions are available in Table 1:

Table 1: Variables Codes and Expected Signs [36]

Variable	Definition	Codes of Variable	Expected sign	Source
dependent Variable	Per capita GDP (constant 2005 US$),	Y_{it}		WDI, 2020
Independent Variable	ICT Index**	$ICT = \frac{1}{m}\sum_{j=1}^{m}\left(\frac{F_j, it}{F_j}\right)$	+	WDI, 2020
	Human Capital	L_{it}	+	Penn Tale 10.0*

	Capital Stock	K_{it}	+	Penn Tale 10.0*
Control Variables	Inflation, GDP deflator (annual %)	INF	-	WDI, 2020
	General government final consumption expenditure (% of GDP)	GFCEX	-	WDI, 2020
	Trade (% of GDP).	T_{it}	+	WDI, 2020

Human capital index, based on years of schooling and returns to education. Capital Stock is (Capital stock at current PPPs (in mil. 2017US$)). ** The ICT index (GEC) is constructed by using the weighted average of fixed telephone subscriptions (Ln FXTEL); and mobile cellular subscriptions (LMbCS)

2.2. Hypotheses

H1: Increased adoption and utilization of Information and Communication Technology (ICT) in the GCC region positively contributes to economic growth.H2: Higher levels of global trade would have a significant positive impact on economic growth in the GCC countries.H3: There is a bidirectional causality between ICT development and global trade, meaning that ICT development fosters global trade, and increased global trade also spurs further ICT development.H4: Global trade through its interaction with technology positively influences economic growth in the GCC countries.

2.3. Empirical estimation strategy

The study uses panel data approach to consistently draw on the ICT's significant effect in influencing global trade impact on GCC's economic growth. The estimation models adopted in this study include Panel Cointegration methodology, which is used to test for the existence of a long relationship between the variable. In addition, fully modified least square (FMOLS) and dynamic ordinary least square (DOLS) are used to test the magnitude of the long relationship among variables:Pedroni's cointegration test: To test the null hypothesis that there is no cointegration in nonstationary panels, [2] presented seven test statistics. The panel's short-run dynamics as well as its long-run slope and intercept coefficients might be heterogeneous because to the seven test statistics. This tool, unlike conventional time-series analysis, does not take into account normalization or the precise number of cointegrating connections. The Kao test is a statistical procedure used to determine if cointegration is present in a dataset of time series. A long-term link between two or more non-stationary time series variables is implied by cointegration. For panel data, which includes information on several entities (cross-sections) recorded over time (time series), [1] is very helpful. The Johansen cointegration tests are a set of statistical tests used to assess the presence and number of cointegrating relationships among a set of non-stationary time series variables. Cointegration suggests a long-term link between these variables, notwithstanding the possibility that they may each be non-stationary separately. These tests, which [3] created, are often used in time series analysis and econometrics. The Trace test and the Maximum Eigenvalue test are the two main Johansen cointegration tests. Fully Modified Least Squares (FMOLS): is an econometric technique used in time series analysis, particularly in the field of cointegration and error correction modeling. It is an extension of the ordinary least squares (OLS) regression method that addresses issues related to spurious regression and endogeneity in time series data. FMOLS is commonly used when analyzing non-stationary time series data, which means that the statistical properties of the data, such as mean and variance, change over time. In the presence of non-stationarity, a simple OLS regression can lead to misleading results, as it may produce spurious correlations. Spurious regression occurs when two non-stationary time series variables are regressed against each other, and the OLS estimates suggest a relationship that does not exist in reality. Apply the FMOLS technique to estimate the parameters of the cointegrating relationship, taking into account the potential endogeneity and spurious regression issues. FMOLS estimates are fully modified because they adjust for serial correlation, heteroscedasticity, and other issues that may affect the standard errors of OLS estimates. Dynamic Ordinary Least Squares (DOLS): is another econometric technique used in time series analysis, especially for modeling relationships between non-stationary time series variables. Like Fully Modified Least Squares (FMOLS), DOLS is designed to address the issues of spurious regression and

endogeneity that often arise when dealing with non-stationary time series data. However, DOLS has a specific focus on modeling the long-run relationships between variables in a dynamic context.

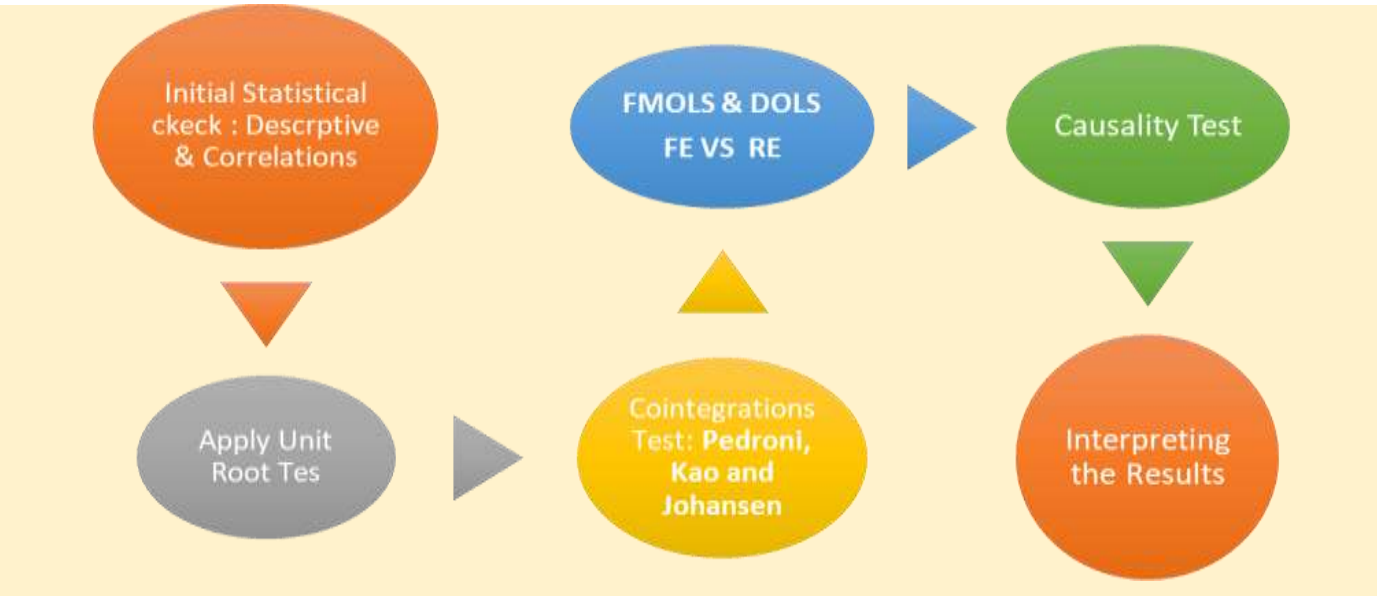

Figure 1. Analytical framework

3. RESULTS AND DISCUSSIONS

3.1Summary statistics and correlations

Table 2 below lists the descriptive statistics, minimum, maximum, mean, and standard deviation (Std. Dev.) of these variables. INF reaches a maximum value between 1990 and 2022 of 144.6836 and has a high standard deviation of 22.47127.

Table 2: Model variable summary statistics [36]

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	CV
LNY	4.486011	4.439326	4.853330	4.197094	0.206378	0.04600
LNT	1.998123	1.968410	2.322552	1.716643	0.125915	0.06301
LNL	0.376174	0.361300	0.521302	0.293133	0.050921	0.13537
LNK	0.186686	0.010077	1.000000	0.000737	0.366351	1.96239
INF	7.972007	4.686541	144.6836	-25.9584	22.47127	2.81877
GFCEX	20.06323	19.76228	76.22213	3.513854	8.566177	0.42696
LIC*TR	8.963909	9.126071	10.32770	7.333234	0.690462	0.07703

Table 3 shows that GDP per capita (LNY), Trade Openness (LNT), Human Capital Index (L) and the interaction term between ICT and trade (LIC*LNT) exhibited small variations across the GCC countries during the period 1990-2020, as indicated by the coefficient of variation (CV). However, inflation rate (INF) and Capital Stock (K) have shown to some extent, great variations, amounting to 2.8 percent and 1.9 percent for the 2 variables respectively. This might be the case of fluctuations in oil prices and food prices during the mentioned period. Table 2 shows the correlation matrix. The correlation showed a positive correlation with all variables except GFCEX.

Table 3: Correlation Matrix for the Model Variables [36]

Variable	LNGDPGR	LTROP	LHC	KSTC	INF	GFCEX	LIC*TR
LNY	1.000000						
LNT	0.011794	1.000000					
LNL	0.038807	0.141991	1.000000				
LNK	0.403051	0.247399	0.307196	1.000000			
INF	0.242994	-0.11583	-0.20136	-0.10765	1.000000		
GFCEX	-0.286161	-0.34384	-0.43215	-0.5268	0.096778	1.000000	
LNIC *LNT	0.596527	0.809156	0.145322	0.447014	0.045523	-0.445953	1.000000

3.2. Panel Unit Root Test

The study employs four sets of unit root tests to ascertain the order of integration, as shown in Table 4. Table 3's results indicate that all variables—aside from INF and the interaction term (LNIC*LNT)—are non-stationary at all levels. With the exception of K, which became stationary after the second difference, all the variables were proven to be stationary after taking the first difference. Therefore, in light of these results, we may move forward with the panel cointegration test to determine if the variables in our panel data have a long-run equilibrium relationship.

Table 4: Panel unit root **test [36]**

Variables	**Levin, Lin & Chu t**		**Im, Pesaran and Shin W-stat**		**ADF - Fisher Chi-square**		**PP - Fisher Chi-square**	
	Level *p*-value	First Difference *p*-value	Level *p*-value	First Difference *p*-value	Level *p*-value	First Difference *p*-value	Level *p*-value	First Difference *p*-value
LNY	0.4798	0.0051	0.2722	0.0003	0.3566	0.0000	0.1080	0.0000
LNT	0.0299	0.0000	0.0034	0.0000	0.0006	0.0000	0.0046	0.0000
LNL	0.0184	0.0393	0.2097	0.4201	0.0071	0.6218	0.0000	0.7172
LNK	0.9692	0.0246	1.0000	0.0000	0.9988	0.0000	0.9993	0.0000
INF	0.0003	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GFCEX	0.3458	0.0000	0.9020	0.0000	0.9047	0.0000	0.2496	0.0000
LC_IC*LNT	0.0197	0.0000	0.0077	0.0000	0.0026	0.0000	0.0480	0.0000

3.3. Lag length criteria for Cointegration

Before running the cointegration analysis, the appropriate lag length criteria for cointegration were selected, as shown in Table 5 After running the model, we found that the criteria of AIC, HQ, final prediction error (FPE) and Sequential likelihood ratio (LR) called for three lags. Hence, lag three is considered as optimum lag in our model.

Table 5: VAR Lag Order Selection Criteria [36]

Lag	LogL	LR	FPE	AIC	SC	HQ

0	-245.9697	NA	9.22E-08	3.666227	3.814711	3.726567
1	1368.682	3042.097	1.29E-17	-19.02437	-17.83650	-18.54165
2	1539.964	305.3291	2.21E-18*	-20.79658*	-18.56932*	-19.89148*
3	1580.196	67.63565	2.54E-18	-20.66950	-17.40286	-19.34202
4	1598.141	28.34824	4.08E-18	-20.21943	-15.91340	-18.46957
5	1644.398	68.38070	4.43E-18	-20.17969	-14.83427	-18.00744
6	1702.046	79.36985*	4.16E-18	-20.30501	-13.92021	-17.71039
7	1748.657	59.44568	4.72E-18	-20.27039	-12.84619	-17.25338
8	1782.876	40.17064	6.64E-18	-20.05618	-11.59259	-16.61679

* indicates lag order selected by the criterion.

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

3.4. Lag length criteria for Cointegration

Having confirmed the order of integration of the panel series, the next step is to check the possibility of long-run relationship between variables. So, [2], [1], [3] co-integration tests are applied to check for Cointegration. The null hypothesis for all tests is that there is no Cointegration in the series, and the alternative hypothesis is that there is Cointegration in the series.

$$H0: \alpha i = 0 \qquad \text{Cointegration does not exist for } \forall j$$

$$H1: \alpha i < 0 \qquad \text{Cointegration does exist for } \forall j$$

Table 6, 7and 8 report the results of the panel Cointegration tests. The Results of [2] test which reported in Table 5, show mixed results because of the use of different tests such as within-group tests (panel statistics) and between-group tests (group statistics). The table reports eleven test results, and we were able to reject the null hypothesis of no cointegration for only six tests and, subsequently, by majority decision, we conclude that there is evidence of cointegration between the variables in our panel data set as the all the coefficients are statistically significant at 5% level percent.

Table 6: Results of Pedroni's Residual Cointegration [36], [37]

	No Deterministic Trend		Deterministic Intercept and Trend		No Deterministic Intercept or Trend	
Alternative hypothesis: Common AR coefficients.	**(Within-dimension)**					
	Statistics (Prob.)	**Weighted Statistic (Prob.)**	**Statistics (Prob.)**	**Weighted Statistic (Prob.)**	**Statistics (Prob.)**	**Weighted Statistic (Prob.)**
Panel v-Statistic	0.8779	0.9786	0.9781	0.0041	0.0041	0.9950
Panel rho-Statistic	0.6310	0.9335	0.9612	0.9951	0.7751	0.0034
Panel PP-Statistic	0.0012	0.0200	0.2271	0.0033	0.3186	0.0000
Panel ADF-Statistic	0.0014	0.0000	0.0031	0.0000	0.5414	0.0000
(Between-dimension)						
Group rho-Statistic	0.8652		0.9928		0.9634	
Group PP-Statistic	0.0000		0.0000		0.0000	
Group ADF-Statistic	0.0000		0.0000		0.0300	

Table 7: Results of Kao's Residual Cointegration Test [36]

			t-Statistic	Prob.
ADF			-3.740509	0.0001
Residual variance			*0.000196*	
HAC variance			*0.000216*	

Table 7 below show the results of Johansen Cointegration test. The trace test indicates seven Cointegration equations while max-eigen test have nine Cointegration equations at the 0.05 level.

Table 8: Johansen Fisher Panel Cointegration Test [36]

Hypothesized No. of CE(s)	Fisher Stat.* (From trace test)	Prob.	Fisher Stat.* (From max-eigen test)	Prob.
None	166.3	0.0000	74.71	0.0000
At most 1	80.95	0.0000	37.74	0.0000
At most 2	49.04	0.0000	25.16	0.0051
At most 3	30.27	0.0008	20.31	0.0264
At most 4	18.51	0.0469	17.82	0.0580
At most 5	12.36	0.2618	12.36	0.2618

**MacKinnon-Haug-Michelis (1999) p-values

Table 8 show the results of Johansen co-integration test. The trace test indicates five co-integrating equations at the 0.05 level. The results of the [3], [2], [1] tests agree. Thus, it can be concluded that the all variables have robust long-run association in GCC countries.

3.5. Error correction model results

The results of the vector error correction model (VECM). The Error Correction Term (ECT) showed a negative and significant coefficient. This result indicates that approximately 0.16 per cent of total disequilibrium in growth rate of GCC will be corrected each year in Table 9

Table 9: VECTOR Error correction model (VECM) [36]

Error Correction:	D(LNY)	D(LNIC_LNT)	D(LNL)	D(LNT)	D(INF)	D(LNK)
CointEq1	- 0.162379	0.577280	0.040801	-13.21487	86.53302	-0.035673
	(0.06641)	(0.44299)	(0.01891)	(25.5812)	(55.0889)	(0.03448)
	[-2.44523]	[1.30316]	[2.15731]	[-0.51658]	[1.57079]	[-1.03455]

3.6. FMOLS and DOLS results

The estimation of the long-run parameters comes next. Several other econometric techniques are suggested because OLS produces false coefficients when cointegration is present. The panel dynamic OLS (DOLS), one such approach, is thought to produce superior outcomes for cointegrated panels. However, a significant flaw with DOLS is that it ignores the problem of cross-sectional heterogeneity. For cointegrated panels, [36],[2] presented the fully modified OLS (FMOLS) estimator, which accounts for the cross-sectional heterogeneity, endogeneity, and serial correlation issues. The FMOLS method is also thought to offer reliable estimates in small samples. The results of both FMOLS and DOLS are reported in Table 9. Based on the evidence of the long association and co-integration between the variables at 5% significance level, we can proceed further to estimate the magnitude of the long run relationship between the variables by applying panel Fully Modified Ordinary Least Squares (FMOLS) and panel Dynamic Ordinary Least as shown in Table 10.

TABLE 10: FMOLS AND DOLS Results [36]

Variable	FMOLS	DOLS
LLIC_LNT	0.501108 0.011152 (44.93372} **	0.487093 0.006180 (78.81819} **
LNT	-2.213840 0.056549 (-39.14899} **	-2.151626 0.035530 (-60.55720} **
INF	3.12E-05 3.98E-05 (0.782791}	5.61E-05 1.88E-05 (2.984536} **
LNL	-0.030899 0.038813 (-0.796101} **	-0.009726 0.020029 (-0.485595}
LNK	0.108473 0.050101 (2.165065) **	0.010976 0.042465 (0.258472)
GFCEX	-5.22E-05 0.000135 (-0.385969)	-0.000165 8.49E-05 (-1.943321)

LIC	0.000513 0.002718 (0.188879)	-0.003960 0.001912 (-2.071450) **

The results of both FMOLS and DOLS are reported in Table 10. The results show that the interaction term (LIC*TROP), and trade openness (LNTROP) are statistically significant in both (FMOLS and DOLS Methods) as p-values are less than 10 percent, 5 percent and 1 percent significance levels. For inflation rate (INF), human capital index (HC) and ICT (LNIC) variables, their results are significant in one model of analysis and insignificant in the other and with reverse signs. Government spending variable (GFCEX) came with the correct sign but insignificant.

3.7. Fixed Effect Results

To decide between fixed effect model or random effect model, we run simple Hausman test where the null hypothesis is that the fixed effect model is more appropriate vs. the alternative hypothesis the random effect model is more appropriate.

H0: Random Effect Model is appropriate

H1: Fixed Effect Model is appropriate

Table 11 show the result of the hausman test as the p-value >0.05 then Ho is rejected, so we select the Fixed effect model (FEM).

Table 11: Hausman Test Result [36]

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	95.025320	5	0.0000

As the Hausman test is in favor of fixed effect model, we run regression for panel fixed effect to test for panel heterogeneities and the results are given in Table 12. As the initial step, we examine the impact of ICT, and international trade on economic growth. It is found that LDIGEC_TROP and KSTC, have a positive and significant effect on growth for GCC countries. Trade openness and, LTROP are significant but with negative signs. Inflation, GFCEX and LIC are insignificant.

Table 12: **Fixed** Effect Results [36]

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNIC_LNT	0.510317	0.004472	114.1118	0.0000
LNT	-2.279511	0.019416	-117.4013	0.0000
INF	1.28E-05	2.27E-05	0.562593	0.5744
LNL	-0.040290	0.020417	-1.973312	0.0501
LNK	0.146225	0.028675	5.099477	0.0000
GFCEX	-0.000136	7.78E-05	-1.748713	0.0821
LIC	-0.001984	0.001532	-1.294465	0.1972
C	4.455706	0.016545	269.3042	0.0000
	Effects Specification			
Cross-section fixed (dummy variables)				
R-squared	0.999256	Mean dependent var		4.486011
Adjusted R-squared	0.999204	S.D. dependent var		0.206378

S.E. of regression	0.005823	Akaike info criterion	-7.386669
Sum squared resid	0.005866	Schwarz criterion	-7.161214
Log likelihood	699.9602	Hannan-Quinn criter.	-7.295306
F-statistic	19350.80	Durbin-Watson stat	0.455996
Prob(F-statistic)	0.000000		

3.8. Results of Granger-Causality Tests

The existence of cointegration between the variables in our present study does not indicate the direction of causality between these variables, hence we need to examine the direction of causality between the variables using the Panel Granger causality test. Table 13reveals the causality effect of the variables of interests adopted in this paper. The analysis shows that there is unidirectional causality running from LNIC*LNT and LNT to real growth rate.

Table 13: Granger Causality **Tests [36]**

Variables	F-Stat.	p-value	Causality
LNT → LNY	5.39480	0.0055	Yes
LNL → LNY	0.66912	0.6978	No
LIC_LNT → LNY	2.16167	0.0418	Yes
INF → LNY	1.29330	0.2771	No

4.CONCLUSIONS

The GCC nations of Bahrain, Kuwait, Qatar, Oman, the Kingdom of Saudi Arabia, and the United Arab Emirates are the focus of the paper's discussion of the growth effects of ICT and international trade. The study examines whether the ICT and global trade have a favorable impact on GCC nations by using a panel, data technique for the years 1990 to 2022. The study used a four-panel unit root test to verify the series initially, and the findings demonstrate that all the series are integrated of order one after the first and second differences. Panel co-integration methodology is used to test for the existence of a long relationship between the variables. Three tests, [2], [1], [3] cointegration tests are applied to check for co-integration. The results of the three tests reveal that there exists a long run co-integrating relationship between the variables and economic growth in GCC countries. To test the magnitude of the long relationship among variables fully modified least square (FMOLS) and dynamic ordinary least square (DOLS) were used. The results show that ICT and global trade variables are positive and have significant impact on the long run growth of the economy. The Granger causality results suggested a bidirectional causal link between economic growth and ICT and global trade variables was found to exist. No causal link was found between human capital, inflation rate and economic growth. Further, fixed –effects method is selected as random - effect model is rejected based on Hausman test result. The results of fixed effect show ICT and global trade variables are statistically significant. Based on the findings of the study, the study provides the following key points as a conclusion: Positive ICT-Growth Relationship: The study offers compelling evidence of a favorable and reciprocal causal relationship between information and communication technology (ICT) development and economic growth in the Gulf Cooperation Council (GCC) area. This research emphasizes how crucial it is to fund ICT infrastructure and policy in order to promote economic growth in the GCC nations. The research also demonstrates an important link between international trade and economic growth in the GCC area. According to the panel causality study, trade and economic growth reinforce one another, with trade causing economic growth and vice versa. This demonstrates

the GCC nations' reliance on global trade as an engine of economic growth. Synergistic impacts: The study shows that global trade and ICT have positive synergistic impacts on economic growth in the GCC. A strong ICT industry and engaged involvement in international commerce not only promote economic growth but also magnify the effects of both on one another. The necessity for policies that support both ICT growth and trade liberalization is highlighted by this synergy**.** The Policy Recommendations, Develop ICT Infrastructure: Given the beneficial link between ICT and growth, GCC governments should keep funding the construction of ICT infrastructure. Increased high-speed internet access, digital literacy initiatives, and incentives for R&D should all be a priority for policies. These initiatives will boost the region's competitiveness on the international stage while also promoting economic growth. Encourage Digital trade: Policymakers should support programs that encourage digital commerce in order to take advantage of the synergistic impacts of ICT and international trade. To promote safe and secure online transactions, this includes lowering obstacles to e-commerce, harmonizing laws governing cross-border data transfers, and strengthening cybersecurity safeguards. In conclusion, the study's findings show how closely intertwined ICT, international commerce, and economic development are in the GCC area. Utilizing these connections through focused policies can result in long-term economic growth, enhanced competitiveness, and raised living standards for citizens of the GCC nations.

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