Role of Digitalization in High-Technology Exports: A Panel Data Approach for GCC Nations

Sahar Hassan Khayat [1]

[1] Department of Economics, Faculty of Economics and Administration, King Abdulaziz University

Correspondence: Sahar Hassan Khayat, Faculty of Economics and Administration, King Abdulaziz University, Jeddah, Saudi Arabia. E-mail: skhayat@kau.edu.sa

Received: June 25, 2025 Accepted: July 23, 2025 Online Published: August 4, 2025

doi:10.5430/jbar.v14n1p9 URL: https://doi.org/10.5430/jbar.v14n1p9

Abstract

This research asserts that accessibility of new knowledge through information and communication technology (ICT) will prompt high-technological advancement, accompanied by knowledge regarding market dynamics, concurrently driving the growth of high-technology exported goods. The purpose of the study is to investigate the effect of digitalization on the technological sophistication of exports. This study used the ICT development index (IDI), which is a composite index of ICT access, ICT use, and ICT skills to measure digitalization and high-technology exports' value as the proxy to assess export sophistication. For empirical estimation, we used Panel autoregressive distributed lag approach over the period 2010-2020. The findings reveal that in the GCC nations, IDI index and it's all separate components have a substantial contribution in boosting high-technology exports. It is recommended that ICT can be a strategic factor for oil dependent nations by concentrating on high-technology sectors since GCC states endeavoring to upsurge high-technology export, should invest more in ICT

Keywords: Digitalization, ICT development, high-technology exports, ICT access, ICT skill

1. Introduction

The rapid digitalization and technological advancement driven by globalization have led to a modification in trade. This competitiveness and advancements, which are the requisite of today's modern world, have also prompted changes in the diverse exported products (Özsoy et al. 2022). The trade of high-technology products serves as an indicator of a nation's inclusive competitiveness and its status in the international marketplace of technology. It further contributes to recognizing the comparative advantages that high-technology and innovations develop among countries (Tebaldi, 2011). Furthermore, the technological products exports provide higher value addition and enhance the economic performance of the nations in international trade (Falk, 2009). Consequently, nations contend to venture the exports of high-technology and more complicated products that need advancing technology, knowledge and digitalization, as it is imperative not merely for economic development but also the transformation of a country towards contemporary society. Zeufack (2001) emphasizes the evolution into the modern economy from the traditional economy by shifting to the manufacturing of complicated or high-technology products, accompanied by modifications in the structure of simple exports. As a result, high-technology exports are viewed as the significant factors influencing economic growth and development.

Digitalization and ICT (information, communication and technology) are the foundations to create high value-added and technologically based products. ICT significantly contributes to the economic and social development of a nation along with the industrial output of an economy (UNDP, 2001). Consequently, ICT has efficiently lowered the cost of trading, enhanced trade productivity and improved the volume of trade (Adeleye, Adedoyin, & Nathaniel, 2021). Trade driven by the adoption of ICTs provides vibrant advantages and will probably continue to increase in future. Trade is broadly regarded as the leading catalyst for economic prosperity (Fahlevi et al. 2023; Yusuf et al. 2023). Since the revenues from export amenities are considered as the primary source of foreign earnings for least developed and emerging economies. These earnings reduce balance-of-payment pressure and create opportunities for jobs (Luong & Nguyen, 2021).

The existing body of literature advocates the incorporation of complicated and diversified exports has emerged as the need for the analysis of exports. Since not only the exports volumes but its technological intensity are also crucially important for sustained economic growth (Hausman, Hwang, & Rodrik 2007; Minondo, 2010; Rodrik, 2006). The empirical evidence on the considerable contribution of ICT in international trade has been limited so far. Portugal-Perez and Wilson (2012), investigated the influence of different sorts of infrastructure on the performance of exports across developing nations. They concluded that the impact of ICT infrastructure on export performance is significantly important for the transition of a country from a developing to a developed nation. The study of Montobbio and Rampa (2005) empirically investigated the role of technology on trade by using structural decomposition analysis. They found that if the technologically intensive industries grow in a country then export gains are caused due to technology activities in a high-technology sector.

Investment in R&D is the crucial driver in examining high-technology exports (Braunerhjelm and Thulin, 2008). Technological advancement due to R&D activities originates innovation, invention, capital accumulation, and effective use of resources. The technical potential of a nation, enrollment ratio in gross tertiary education, and access to computers drive positive impacts on high-technology exports (Srholec, 2007). Considering the nations' level of digitalization and technological advancement is pertinent to assess their ability to compete globally and export advanced technological commodities. The crucial phase in establishing a association between digitalization and high-technology exports is to identify the variables that accurately represent the proxy variable for ICT (Abedini, 2013). In this research, a composite index called IDI index has been constructed, which is the most comprehensive variable for ICT development. It comprises three primary indicators and their sub-categories that represent their features. The International Telecommunication Union (ITU) identified categories of primary indicators as per the ICT developmental phases of the nations including, ICT access, ICT use, and ICT skills (see Figure 1).

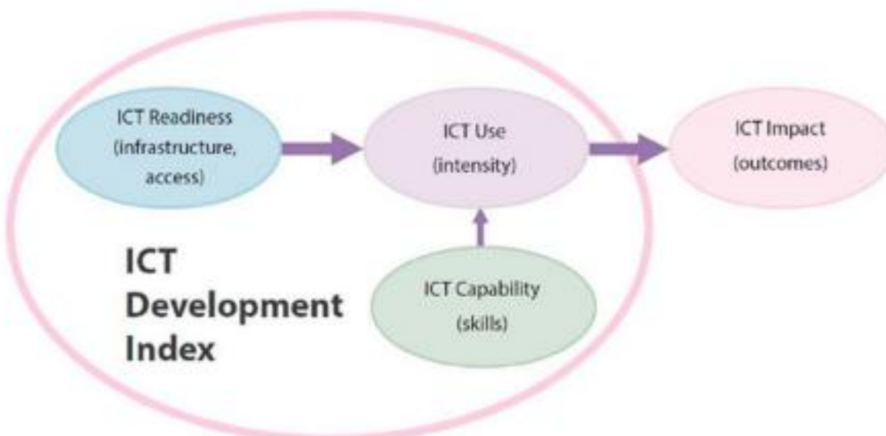

Figure. 1 Stages of ICT development transition into information society (Source: ITU, 2016)

A few previous studies determined the digitalization role on exports. However, Freunda and Weinhold 2004) used internet subscriptions as the proxy variable to assess digitalization. The study of Seyoum (2005) and Abedini, (2013) employed telecommunication and quality of technological infrastructure as the proxy to reflect ICT development. In contrast, this study employs a broad digitalization variable that represents a nation's level of digitalization, known IDI index. The study of Nath and Liu, (2017) and Ozcan (2018) also construct and employ a broad ICT development index but none of them examine the technological intensity of exports.

The World Economic Forum underscored the idiosyncratic array of aspects of GCC nations that provide various prospects for exploiting springing technological solutions to build opportunities. Concerning the spending on ICT development by 2024, UAE is estimated to spend US$ 23 billion, following Kuwait to US$ 10 billion, and the expenditure of Qatar will be approximately US$ 9 billion. ICT development has intensified the digital economy in the GCC region, improved productivity and developed effective channel to link directly to government e-services. Undoubtedly, digital transformation has been prioritized by governments across the GCC nations, observing their socio-economic development plan and a primary element of their corresponding vision 2030. the Report United Nations states that Bahrain, UAE, Qatar, Oman, and Saudi Arabia are among the top five economies across the Arab region and globally within the top 60 in a composite index IDI (positions 166 economies regarding their ICT access, use, and skill level) (Balouza, 2019; Veröffentlicht, 2014).

Based on the above discussion, this research aims to examine the long-term and short-term effects of digitalization and the technological sophistication of exports in GCC economies. For this reason, this study employs high-technology exported goods as the indicator for the technological sophistication of exports and the IDI index as a measure for the extent of digitalization in a particular economy. Conversely, this study determines the effect of digitalization on high-technology exports. Driven by the belief that ICT access, ICT use, and ICT skills influence the transformation into an information society that supports high-technology exports, we are also interested in examining the relationship between IDI index components and high-technology exports.

2. Method

To achieve the purpose of this research, a composite IDI index is used as the proxy to assess the nations' level of digitalization and technological intensity of exports as the proxy to examine the exports of high-technology products. A multivariate panel data framework is employed for GCC states including, Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates for the period 2010-2022. The dependent variable of the study is logarithms of the current value of high-technology exports, which are described as exports of products with high intensity of research and development including, scientific instruments, computers, aviation, pharmaceuticals, chemistry, armaments, electrical and non-electrical machines (World Bank, 2021).

Consequently, the IDI index is used as the main independent variable, proposed by ITU (2016) to indicate the developmental stages of ICT at the national level. It is an all-inclusive index, combining 11 indicators into one index to track ICT development across nations. The IDI index was introduced in 2009 by ITU, to monitor the technology gap and to analyze nations' transitions towards information economies. Hence, it reflects the extent of countries' advancement in ICT development. The ICT development of a nation can be characterized by three phases;

- Phase 1: ICT access – represents the degree of digital connectivity and user accessibility
- Phase 2: ICT use – represents the extent of ICT adoption within the community
- Phase 3: ICT impact – represents the consequence of more effective use of ICT tools
- Proceeding through these phases based on a mixture of following constituents: (1) accessibility and readiness of ICT infrastructure, (2) enhanced extent of ICT use, and (3) effective ICT utilization capabilities. To incorporate all these constituents, constructing a comprehensive index IDI is necessary. Its construction is further broken into three sub-indices (ITU, 2009), which are given as follows (only those components that are covered by this research);

1. Sub-index "Access" includes indicators that capture infrastructure and access regarding ICT. It is estimated by, worldwide Internet bandwidth per Internet user, mobile cellular subscriptions per 100 populations and, fixed broadband penetration rate (per 100 population).
2. Sub-index "Use" incorporates indicators that capture usage and intensity of ICT and it is calculated by the proportion of people consuming the internet and fixed broadband penetration rate (per 100 population).
3. Sub-index "Skills" encompasses indicators such as indispensable inputs that capture the ability and skills of ICT. It is measured by the tertiary and secondary gross enrolment ratio.
4. Since the ITU index is unavailable for the entire studied time frame (2010-2022), this research reconstructs the index using the underlying data available for the relevant period. we adopted the same procedure as used by ITU (2009) by assigning equal weights to indicators incorporated in each sub-index. Consequently, the aggregate value of each sub-index is estimated by averaging the components. Then, the mean and standard deviation are computed for each component within the sub-index groups and reference values are estimated to normalise each component (see Table 1), which is specified as;

$$Reference\ value = mean + 2 * standard\ deviation$$

Table 1. Reference Values Acquired through Statistical Methods

Countries	ICT Access			ICT Use		ICT Skill	
	Fixed-telephone subscriptions per 100 populations	Mobile/cellular subscriptions per 100 populations	International internet bandwidth (bit/s) per internet user	Proportion of people consuming the internet	fixed broadband penetration rate (per 100 population)	Secondary gross enrollment ratio	Tertiary gross enrollment ratio
Bahrain	24.52696	210.8206	977889.1	116.7313	28.1443	108.8365	73.13507
Kuwait	17.03159	207.7915	230046.5	114.6146	2.79723	99.26316	61.44675
Oman	31.89231	438.7615	240524.2	225.1385	20.46923	311.7729	122.1899
Qatar	21.11659	171.1838	264593.5	115.099	12.76231	110.4065	33.55255
Saudi Arabia	19.14551	195.6225	497244.8	119.5332	36.08505	116.8874	95.3233
United Arab Emirates	28.57128	252.3656	891960.4	110.3406	47.08594	130.1848	52.08253

Source: Estimated by the author using the methodology described in ITU (2009).

At the last, we applied a weighting system (principal component analysis (PCA) approach), to sum up the sub-indices into one index. Using PCA, relative weights are allocated to the indicators: ICT use and ICT access are each weighted at 40%, and ICT skills at 20%, as presented in Table 2.

Table 2. Construction of IDI Index

Indicators in IDI Index	Weightage
ICT Access (A) Sub-index = (a1+a2+a3)	
Fixed-telephone subscriptions per 100 populations (a1)	Log(x)*0.33/ Reference value
Mobile/cellular telephone subscriptions per 100 populations (a2)	Log(x)*0.33/Reference value
Worldwide internet bandwidth (bit/s) per internet user (a3)	Log(x)*0.33/ Reference value
ICT Use (B) Sub-index= (b1+b2)	
Proportion of people consuming the internet (b1)	x*0.5/ Reference value
Fixed-broadband subscriptions per 100 populations (b2)	Log(x)*0.5/ Reference value
ICT Skill (C) Sub-index = (c1+c2)	
Secondary gross enrollment ratio (c1)	x/2/(Reference value
Tertiary gross enrollment ratio (c2)	x/2/(Reference value)
Composite Index IDI = (A)*0.4 + (B)*0.4 + (C)*0.2	

Note. Data is transformed into logarithms to eliminate large numbers of high-end outliers. The reference value refers to Table 3.

Source: International Telecommunication Union ITU (2009; 2016).

Furthermore, a bunches of control variables are also used including gross capital formation (% of GDP), GDP per capita, inflation, and ICT goods imports. The variables incorporated in the analysis and their sources are presented in Table 3.

Table 3. Definitions and Sources of Variables

Variables	Definitions	Sources
High-technology exports (Hightech_exp)	It is the log of exports of high-technology products in current US$.	World Bank, World Development Indicators.
IDI_index	ICT development index	Constructed by using methods of the International Telecommunication Union (ITU).
Access Index	ICT Access sub-index	International Telecommunication Union (ITU).
Use index	ICT Use sub-index	International Telecommunication Union (ITU).
Skill index	ICT Skill sub-index	International Telecommunication Union (ITU).
GDP per capita (GDPPC)	Gross domestic product per person in a country (constant 2015 US$).	World Bank, World Development Indicators.
Gross capital formation (GCF)	It is measured as the log of gross capital formation as a percentage of GDP.	World Bank, World Development Indicators.
Inflation (INF)	It is measured by the log of the consumer price index (2010=100), reflecting the rise in prices over a specified period.	World Bank, World Development Indicators.
ICT_imports	It is measured by the imports of ICT products in current US$).	World Bank, World Development Indicators.

2.1 Model Specification

This study used four different models to achieve the aim of the research, where $Z_{i,t}$ is the vector of control variables, t refers to the period and subscript (i) represents the cross-sectional units (countries). Model (1) examines the importance of the IDI index in high-technology exports (main model), which is specified as follows;

$$Hightech\_exp_{i,t} = \alpha_0 + \beta_1 IDI\_index_{i,t} + \gamma Z_{i,t} + \varepsilon_{i,t} \qquad \text{(Model 1)}$$

The Given models from 2 to 4 are specified to investigate the influence of the IDI index's different components such as skill, use, and access of the exports high-technology goods.

$$Hightech\_exp_{i,t} = \alpha_1 + \beta_2 ICT\_accesss_{i,t} + \gamma Z_{i,t} + \varepsilon_{i,t} \qquad \text{(Model 2)}$$

$$Hightech\_exp_{i,t} = \alpha_2 + \beta_3 ICT\_use_{i,t} + \gamma Z_{i,t} + \varepsilon_{i,t} \qquad \text{(Model 3)}$$

$$Hightech\_exp_{i,t} = \alpha_3 + \beta_4 ICT\_\,skill_{i,t} + \gamma Z_{i,t} + \varepsilon_{i,t} \qquad \text{(Model 4)}$$

To observe the associations, this research uses panel data from all six GCC economies from 2010-2022. In econometric analysis, panel data has crucial significance due to its relevance in dynamic procedures (Baltagi 2008). This research follows previous studies on the dynamic panel and uses both Pooled Mean Group (PMG) and Mean Group (MG) estimations to investigate the relationship between exports of high-technology products and the IDI index along with its sub-indices (Pesaran, Shin, & Smith 1999; Pesaran, Shin, & Smith, 1997). The analysis of the study has adopted two steps; (i) the panel unit root test was employed to test the stationarity of the variable and then (ii) the panel autoregressive distributed lag technique (ARDL) to capture the short-run and long-run effects.

2.1.1 Panel Unit Root Test

To select the adequate model, it is necessary to evaluate the order of integration for the stated variables. To prevent the analysis from the spurious regression issue, two-panel unit root tests have been used based on combined and individual effects. The Levin, Lin, Chu (LLC) test (2002) is based on Dickey Fuller method, which allows homogeneity in entire cross-sectional units in the dynamic panel of auto regression while the Im, Pesaran, and Shin (IPS) test (2003) permits unit root process for individual units. To develop the panel-specific findings, all the assessments are distinguished by the amalgamation of individual unit root tests and provide the benefits of permitting more heterogeneity across all cross-sectional units.

The simple regression method for LLC

$\Delta y_{it} = \mu_i + \rho y_{it-1} + \sum_{j=1}^{m} \alpha_j \Delta y_{it-j} + \delta_{it} + \theta_{it} + \epsilon_{it}$ (2)

Where Δ represents the 1st-difference operator, m denotes the length of the lag, μi, and θit are unit-specific representing fixed and time effects. The null hypothesis is that for all panel units, ρi = 0 indicating time series are non-stationary whereas, the alternative hypothesis indicates stationarity among time series, ρi < 0 for all panel units.

On the other hand, the IPS test is also used to check the occurrence of unit roots in the panel dataset that integrates the information from both cross-sections and time series dimensions, thus few observations related to time are needed for the test to provide robust results. The regression method for the IPS test is as follows,

$\Delta y_{it} = a_i + \rho_i y_{it-1} + \sum_{j=1}^{pi} \beta_{ij} \Delta y_{it-j} + \epsilon_{i,t}$ (3)

IPS test based on the null hypothesis ρi = 0, for all i = 1,……, N. While, the alternative hypothesis is ρi < 0 for i = 1,…… N1.

2.1.2. Co-integration Test

This study employs panel co-integration tests introduced by Kao (1999) to examine a long-run equilibrium association among the studied variables, after performing the panel unit root. If the variables are co-integrated with the mixed order of integration, then we can use the panel ARDL model to test the short=run and long-run link between the variables otherwise we have to adopt another strategy to proceed further.

2.1.3. Panel ARDL Model

In the next step after testing the stationarity of the variables and co-integration, we then progress with the stipulation of the dynamic panel model. When the model has some variables with stationary at the level and some with stationary at the first difference, then the Panel Autoregressive Distributed lag (ARDL) is the most suitable technique to perform. Since the long-run coefficient has been anticipated by the panel ARDL method. Pesaran, Shin and Smith, (1997) proposed an alternative estimating technique pooled mean group (PMG) model as this estimator is the simplified version of ARDL with an unconventional panel setting, which incorporates short-run parameters, intercepts, and co-integration terms. It reflects long-run parameters are identical across the different cross-sectional entities however short-term estimators are heterogeneous. whereas, the mean group (MG) considers country-specific estimates in both short-run and long-run. It measures idiosyncratic regression for each cross-sectional unit (nations) by estimating unweighted averages (Darsono et al., 2022). The Hausman test is applied to select between PMG and MG models to check whether these estimators are significantly different. However, both PMG and MG have relevancy but PMG is more effective under the assumption of homogeneity (Pesaran et al. 1999). Moreover, the endogeneity problem can be controlled in the ARDL model because each regressor bears an individual equation.

The equation of panel ARDL for IDI index can be formulated as,

$$Hightech\_exp_{i,t} = \sum_{j=1}^{p} \beta_{i,j} \Delta Hightech\_exp_{i,t-j} + \sum_{j=0}^{q} \delta_{i,j} \Delta IDI\_index_{i,t-j} + \sum_{j=0}^{q} \gamma_{i,j} \Delta Z_{i,t-j} + \epsilon_{it} \quad (4)$$

Where Z denotes the vector of control variables and the above model can be rewritten as follows after parametrizing the model;

$$Hightech\_exp_{i,t} = \varphi_i (Hightech\_exp_{i,t-1} - \theta_1 IDI\_index_{i,t-1} - \theta_2 Z_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{1i,j} \Delta Hightech\_exp_{i,t-j} + \sum_{j=0}^{q} \lambda_{2i,j} \Delta IDI\_index_{i,t-j} + \sum_{j=0}^{q} \lambda_{3i,j} \Delta Z_{i,t-j} + \mu_{it} + \epsilon_{it} \quad (5)$$

The equation of panel ARDL of IDI index components can also be specified as;

$$Hightech\_exp_{i,t} = \varphi_i (Hightech\_exp_{i,t-1} - \theta_1 ICT\_access_{i,t-1} - \theta_2 Z_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{1i,j} \Delta Hightech\_exp_{i,t-j} + \sum_{j=0}^{q} \lambda_{2i,j} \Delta ICT\_accessI_{i,t-j} + \sum_{j=0}^{q} \lambda_{3i,j} \Delta Z_{i,t-j} + \mu_{it} + \epsilon_{it} \quad (6)$$

$$Hightech\_exp_{i,t} = \varphi_i (Hightech\_exp_{i,t-1} - \theta_1 ICT\_use_{i,t-1} - \theta_2 Z_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{1i,j} \Delta Hightech\_exp_{i,t-j} + \sum_{j=0}^{q} \lambda_{2i,j} \Delta ICT\_use_{i,t-j} + \sum_{j=0}^{q} \lambda_{3i,j} \Delta Z_{i,t-j} + \mu_{it} + \epsilon_{it} \quad (7)$$

$$Hightech\_exp_{i,t} = \varphi_i (Hightech\_exp_{i,t-1} - \theta_1 ICT\_skill_{i,t-1} - \theta_2 Z_{i,t-1}) + \sum_{j=1}^{p-1} \lambda_{1i,j} \Delta Hightech\_exp_{i,t-j} + \sum_{j=0}^{q} \lambda_{2i,j} \Delta ICT\_skill_{i,t-j} + \sum_{j=0}^{q} \lambda_{3i,j} \Delta Z_{i,t-j} + \mu_{it} + \epsilon_{it} \quad (8)$$

The term φi indicates the error correction coefficient (speed of adjustment) which is anticipated to have a statistically significant and negative sign. In notations $\lambda_1, \lambda_2,$ and λ_3 reflect the lagged short-run coefficients of the respective models while θ_1, θ_2, and θ_3 refer to the long-run coefficients.

3. Results

The descriptive statistics presented in Table 4 summarize key variables relevant to the study. High-technology exports have a mean of 18.099, showing moderate variability. IDI index averages 3.196. IDI sub-indices of access, use, and skill show varying levels, with means of 0.031, 0.401, and 0.735, respectively. GDPPC exhibits significant diversity, with a mean of 32,838.99. GCF and INF have lower variability, with means of 3.301 and 4.724. ICT imports vary widely, with a mean of 6.233.

Table 4. Descriptive Statistics of variables

Variables	Mean	Standard Deviation	Min	Max
Hightech_exp	18.099	2.394	10.415	21.890
IDI_index	3.196	0.858	1.051	4.474
ICT_Access	0.031	0.006	0.0201	0.041
ICT_Use	0.401	0.117	0.095	0.617
ICT_Skill	0.735	0.207	0.294	1.009
GDPPC	32838.99	16682.43	17489.23	73493.27
GCF	3.301	0.245	2.552	3.889
INF	4.724	0.073	4.601	4.934
ICT_Imports	6.233	2.897	0.0009	17.185

Table 5 presents the results of unit root tests conducted on various variables to assess their stationarity. Consequently, Levin, Lin and Chu, lm, Pesaran and Shin, Augmented Dickey-Fuller (ADF) – Fisher Chi Square unit root test has been performed to evaluate the stationarity condition of the variables. The null hypothesis of the unit root test indicates that the panel contains unit roots and it is observed that all the variables studied in the research are stationary at 1st order of integration I (1) across all three tests of unit roots.

Table 5. Summary Statistics of Unit Root Test

Variables	Levin, Lin & Chu Unit Root Test		Im, Pesaran & Shin Unit Root Test		ADF – Fisher Chi Square Unit Root Test	
	Level	1st Difference	Level	1st Difference	Level	1st Difference
Hightech_exp	-1.496	-5.901***	-1.975	-3.919***	23.969**	86.745***
IDI_index	-2.742**	-2.202***	-2.062	-2.874***	38.075***	39.099***
ICT_Access	-2.202***	-1.2925*	-1.704	-2.386**	14.539	24.830***
ICT_Use	-2.287***	-5.265***	-4.433***	-3.112***	122.433***	59.825***
ICT_Skill	0.526	-6.9635***	-0.404	-3.224***	9.651	52.760***
GDPPC	-2.875**	1.630	-1.952	-2.602***	24.938***	29.857***
GCF	-3.133***	-2.073***	-1.866	-3.341***	15.185	61.802***
INF	0.097	-2.391***	-1.522	-2.332***	10.020	25.754***
ICT_Imports	-2.399***	-7.514***	-3.063***	-5.731 ***	58.448***	178.485***

Note. significance levels at 1%, 5%, and 10% are represented by (***), (**), and (**). The null hypothesis shows panels contain unit roots.

Table 6 summarizes the results of the cross-dependence tests conducted to determine whether cross-sectional dependence is present in the dataset. The Pesaran CD test yields a statistic of -0.678 with a p-value of 0.4979, indicating that there is no significant cross-sectional dependence. Similarly, the Freidman test shows a statistic of

9.055 with a p-value of 0.1069, also suggesting no significant cross-dependence. The Frees test results are reported with different critical values corresponding to various significance levels. The test statistic is 0.1984, with critical values of 0.2620, 0.3901, and 0.078 at the 10%, 5%, and 1% levels, correspondingly. These outcomes indicate that the Frees test does not provide strong evidence of cross-sectional dependence in the data.

Table 6. Test for Cross Dependence

Cross Dependence test	Statistics	p-value
Pesaran CD	-0.678	0.4979
Freidman	9.055	0.1069
Frees	0.1984 [a]	-0.078
	0.2620 [b]	
	0.3901 [c]	

Note. Critical values from Frees' Q distribution at (a) 10%, (b) 5%, and (c) 1%.

Table 7 presents the results of the Kao test for co-integration, which evaluates the existence of a long-run equilibrium association among the variables. The null hypothesis of the Kao test indicates no co-integration. These results indicate strong evidence of co-integration among the variables, suggesting that they share a stable, long-term relationship. The rejection of the null hypothesis of no co-integration across all tests confirms that the variables are linked in a way that persists over time, despite short-term fluctuations.

Table 7. Kao Test for Co-integration

Kao test	Statistics	p-value
Modified Dickey-Fuller t	-7.7221	0.0000
Dickey-Fuller t	-8.0798	0.0000
Augmented Dickey-Fuller t	-3.5099	0.0002
Unadjusted modified Dickey-Fuller t	-7.7590	0.0000
Unadjusted Dickey-Fuller t	-8.0830	0.0000

Table 8 explores the long-run and short-run associations between high-technology exports and the IDI index, accompanied by other control variables. It is observed in the table that the p-value of the Hausman test is 0.589, indicating the acceptance of the null hypothesis which states that PMG and MG both are consistent but MG is not efficient. Therefore, following the Hausman test suggestion, PMG analysis has been considered. In the long run, IDI index has a significant positive effect on high-technology exports, with a coefficient of 10.013 and a p-value of 0.000, indicating a 1% increase in the IDI index will increase 10% in exports of high-technology exports. Moreover, GDPPC and GCF are significantly but negatively affecting the high-technology exports. while INF and ICT imports have insignificant long-term impacts. In the short run, IDI index exhibits a significant negative impact on high-technology exports (coefficient = -5.864, p-value = 0.010), indicating that short-term increases in IDI index are linked to decreases in high-technology exports. One possible reason for this short-run negative relationship is that ICT investment might at first crowd out resources for instances financial capital, labor, or institutional attention that could otherwise be directed to underpinning export activity. Other variables, including GDPPC, GCF, INF, and ICT imports, do not show significant short-run effects. The error correction term (ECT) has an expected sign with a significant impact, indicating a speed of adjustment (-0.949) towards long-term equilibrium after deviation.

Table 8. Long-run and Short-run association among High-Technology Exports and Composite IDI Index.

Variables		**Co-efficient**	**Standard Error**	**Z-statistics**	**p-value**
Long-run Estimators	IDI_index	10.013	2.875	3.48	0.000
	GDPPC	-0.000087	0.000044	-1.99	0.047
	GCF	-2.721	1.207	-2.25	0.024
	INF	-5.781	3.234	-1.79	0.074
	ICT_Imports	0.1058	0.063	1.66	0.098
Short-run Estimators	D(IDI_index)	-5.864	2.270	-2.58	0.010
	D(GDPPC)	0.00017	0.00019	0.90	0.367
	D(GCF)	1.223	0.709	1.72	0.085
	D(INF)	15.255	23.487	0.65	0.516
	D(ICT_Imports)	0.072	0.247	0.29	0.771
	_cons	41.859	14.011	2.99	0.003
	ECT	-0.949	0.320	-2.96	0.003
Hausman Test	0.589				

The impact of IDI index components such as access (Model 2), use (Model 3) and skills (Model 4) on exports of high-technology exports is illustrated in Tables 9-10. The p-value of Hausman statistics in all three models is greater than 0.05, indicating the acceptance of the null hypothesis and thus PMG is the most suitable model for the analysis of IDI index components. It is observed that all three IDI index components have a positive and statistically significant influence on high-technology exports in the long run. This indicates that ICT infrastructure, ICT use, and ICT skill significantly stimulate unique information which accelerates exports of high-technology goods. However, in the short run, all IDI index components do not provide a significant impact on high-technology exports. Consequently, most of the control variables have an insignificant impact on high-technology exports in the presence of IDI index components. Moreover, the error correction term (ECT) has a negative and significant sign in all three models, suggesting long-run adjustment towards equilibrium.

Table 9. Long-run and Short-run Relationship among High-Technology Exports and ICT Access Index

	Variables	**Co-efficient**	**Standard Error**	**Z-statistics**	**p-value**
Long-run Estimators	ICT_access	0.0171	0.0068	2.51	0.012
	GDPPC	-0.00031	0.00005	-6.08	0.000
	GCF	-9.223	1.393	-6.62	0.000
	INF	8.315	4.377	1.90	0.057
	ICT_Imports	0.1483	0.0325	4.56	0.000
Short-run Estimators	D(ICT_access)	-0.0116	0.010	-1.10	0.271
	D(GDPPC)	0.0033	0.00027	1.49	0.136
	D(GCF)	3.972	2.020937	1.97	0.049
	D(INF)	-10.585	10.144	-1.04	0.297
	D(ICT_Imports)	-.0318	0.1405	-0.23	0.821
	_cons	13.717	7.579	1.81	0.070
	ECT	-0.754	0.297	-2.53	0.011
Hausman Test	0.893				

Table 10. Long-run and Short-run Relationship among High-Technology Exports and ICT Use Index

	Variables	Co-efficient	Standard Error	Z-statistics	p-value
Long-run Estimators	ICT_use	0.0336	0.0116	2.90	0.004
	GDPPC	-0.00017	0.000040	-4.46	0.000
	GCF	-6.493	1.065	-6.10	0.000
	INF	10.294	3.216	3.20	0.001
	ICT_Imports	0.085	0.068	1.25	0.211
Short-run Estimators	D(ICT_use)	-0.033	0.113	-0.29	0.770
	D(GDPPC)	-0.000030	0.00023	-0.13	0.898
	D(GCF)	1.194	1.634	0.73	0.465
	D(INF)	3.591	6.225	0.58	0.564
	D(ICT_Imports)	-0.0729	0.229	-0.32	0.750
	_cons	-4.481	1.715	-2.61	0.009
	ECT	-0.797	0.299	-2.66	0.008
Hausman Test	0.687				

Table 11. Long-run and Short-run Relationship among High-Technology Exports and ICT Skill Index

	Variables	Co-efficient	Standard Error	Z-statistics	p-value
Long-run Estimators	ICT_skill	10.805	0.803	13.45	0.000
	GDPPC	-0.834	0.437	-1.91	0.057
	GCF	-9.336	.000028	-0.33	0.743
	INF	-0.534	2.143424	-0.25	0.803
	ICT_Imports	0.005	0.0201	0.26	0.799
Short-run Estimators	D(ICT_skill)	-6.687	10.753	-0.62	0.534
	D(GDPPC)	-0.00092	0.00096	-0.95	0.341
	D(GCF)	-0.773	1.322	-0.58	0.559
	D(INF)	3.046	15.195	0.20	0.841
	D(ICT_Imports)	0.1387	0.265	0.52	0.601
	_cons	10.541	7.031	1.50	0.134
	ECT	-0.789	0.441	-1.79	0.047
Hausman Test	0.821				

4. Discussion

The results of this research predominantly support the existing literature on the relationship between exports and ICT development, specifically concentrating on GCC states. This research comprehensively analyzed the impact of ICT development on the dynamics of exports of high-technology products employing a dataset over the period 2010-2022.

The empirical findings demonstrate a positive and significant influence of the IDI index on high-technology exported goods in the long term, which supports an extensive debate on the contribution of technology-based system in improving foreign trade. The study of Fahlevi et al. (2024) also demonstrates the positive influence of ICT development on exports and highlights the tangible advantages of ICT investment for societies pursuing to promote their profile of international trade. These results suggest that IDI index indicates a expansion of digital tools and capabilities of a nation that would assist the absorption and adoption of knowledge-based and technological solutions

(ITU, 2017). However, in the short-run significantly but negatively affects high-technology exports. This finding could be due to a crowding-out effect, whereby initial ICT investments reallocate essential resources such as capital, labor, and policy attention away from export activities. Firms in this transitional period may experience adjustment problems and disruption in operations, postponing the occurrence of productivity benefits from digitalization. Jenkins and Edwards (2015) also supported this results as they demonstrated that in South Africa and Brazil, that low-technology exports were crowded-out in developed markets and high-tech exports were crowded-out in regional markets, representing that export competitiveness varied by both type of product and market context. Consequently, the country's extent of digitalization is an ingredient that stimulates access to innovative knowledge and thereby promotes a surge in exports of high-technology products. These results are consistent with the approach of the technology gap. As emerging economies imitate already existing innovative technology of developed nations, accelerating exports of high-technology products enables emerging nations to reproduce the advanced technology that they export. Hence, the technology gap with developing nations is reduced by emerging economies with the exports of high-technology products. Furthermore, the results of IDI index dimension of use, skill and access all have favourable and substantial impacts on high-technology exported goods for GCC states in the long term. However, all components of IDI index have a negative but insignificant impact. The process of ICT development is illustrated by the access, use, and skill components. Access indicates digital connectivity framework and the extent of ICT availability, use represents the concentration of ICT utilization while skills reflect the extent of proficiency needed for dissemination and absorption of ICT. The positive and significant impact of all these variables, in the long run, reveals that ICT infrastructure, use, and skills would prompt innovative information that stimulates exports of high-technology goods comprehensively. Özsoy et al. (2022), also found a positive impact of IDI index and its three components on high-technology exports in developed and developing nations.

On the other hand, the long-term impact of GDP per capita is statistically significant but negative across all the models except ICT skill components. This indicates that per capita income might reduce due to short-term disparities during the transitional period. This result aligns with Fahlevi et al. (2024), which also underscored the negative impact of GDP per capita on exports in the long run. Similarly, inflation also has a positive and statistically significant impact in the long run while imports of ICT products have an insignificant impact. Moreover, gross domestic product negatively and significantly affects the high-technology exports in all models. This finding supports KAbAKLARLI et al. (2018) also indicates a long-term negative impact of investment on high-technology exports.

5. Policy Implication

This study provides several policy implications such as the government of GCC nations must prioritise considerable investment in ICT infrastructure. This can facilitate domestic firms to integrate into international value chains. Policymakers should create awareness and training programs that concentrate on digital skills, and technological competencies. Consequently, improving digital literacy would ensure that the individual can efficiently use and contribute to new technologies. Moreover, the concerned authorities should develop incentives for R&D in high-technology sectors, leading creation of innovative technologies that can accelerate high-technology exports. Further, GCC states are heavily dependent on oil products however ICT can be a driver for diversification away from oil dependency by concentrating on high-technology sectors, allowing the advancement of new firms that can compete internationally.

6. Conclusion

In economic terms, exports are considered actual outcomes whereas economic activity is often evaluated based on expected outcomes. An expansion in exports has potentially to lead increase in the level of production. Consequently, countries aiming to compete globally with high-value-added products rather than low-value-added and traditional products must prioritise a production model that depends on information and knowledge. To consider this, an amalgamation of information and knowledge with modern technologies of production such as digitalization is crucial in stimulating the level of exports. exports can be increased with the traditional structures of production but an increase in its value is only possible with high-technology exports enacted by international markets. This dynamic induces us to interconnect ICT, digitalization and high-technology exports. Therefore, this research aims to investigate the impact of ICT development on a nation's level of exports of high-technology products. The empirical evidence provides the statistically significant and positive impact of IDI index on the exports of high-technology products in the long run. This suggests the digitalization level of nations is an element that stimulates the availability of economies to new knowledge and thereby significantly promotes high-technology exports. Consequently, we also found ICT infrastructure, ICT utilization, and skills required for the usage of ICT contribute significantly to the exports of high-technology exports.

7. Limitation and Future Direction

This study has some limitations that would be the base of research in future. The bunch of economies we studied in the analysis are the members of the Gulf Cooperation Council (GCC), in terms of institutional framework and economic development they exhibit quite homogenous characteristics, which may limit the generalizability of the findings to other regions with different economic and digitalization structures. Future research could further the investigation beyond the GCC countries to encompass comparative cross-regional or developing versus developed economies, providing greater generalizability. Moreover, while it is known that trade policy and exchange rates are significant determinants of export performance, these variables are omitted from the analysis because of concerns with data availability as well as the focus of the study on ICT-related variables. Future studies could integrate additional macroeconomic variables including trade openness exchange rates, and tariff structures, which affect the relationship between the high-technology exports and ICT development. Furthermore, in future studies, researchers can also assess the role of FDI investment from multinational corporations to instigate high-technology exports since technological spillover impact with FDI investment also plays a critical role in high-technology exports.

Acknowledgments

The author is very thankful to all the associated personnel in any reference that contributed to/for this research.

References

Abedini, J. (2013). Heterogeneity of trade patterns in high-tech goods across established and emerging exporters: A panel data analysis. *Emerging Markets Finance and Trade, 49*(4), 4-21. https://doi.org/10.2753/REE1540-496X490401

Adeleye, B. N., Adedoyin, F., & Nathaniel, S. (2021). The criticality of ICT-trade nexus on economic and inclusive growth. *Information Technology for Development, 27*(2), 293-313. https://doi.org/10.1080/02681102.2020.1840323

Balouza, M. (2019). The impact of information and communication technologies on the human development in the gulf cooperation council countries: An empirical study. *Management Studies and Economic Systems, 4*(2), 79-113. https://doi.org/10.12816/0055079

Baltagi, B. H. (2008). Forecasting with panel data. *Journal of forecasting, 27*(2), 153-173. https://doi.org/10.1002/for.1047

Braunerhjelm, P., & Thulin, P. (2008). Can countries create comparative advantages? R&D expenditures, high-tech exports and country size in 19 OECD countries, 1981-1999. *International Economic Journal, 22*(1), 95-111. https://doi.org/10.1080/10168730801887026

Darsono, S. N. A. C., Wong, W. K., Nguyen, T. T. H., & Wardani, D. T. K. (2022). The economic policy uncertainty and its effect on sustainable investment: A panel ARDL approach. *Journal of Risk and Financial Management, 15*(6), 254. https://doi.org/10.3390/jrfm15060254

Fahlevi, M., Ahmad, M., Balbaa, M. E., Wu, T., & Aljuaid, M. (2023). The efficiency of petroleum and government health services to benefit life expectancy during the inefficiencies of hydroelectricity consumption. *Environmental and Sustainability Indicators, 19*, 100289. https://doi.org/10.1016/j.indic.2023.100289

Fahlevi, M., Asdullah, M. A., Raza, F. A., Watto, W. A., Aljuaid, M., & Aziz, A. L. (2024). The influence of information and communication technology on trade in developing countries and partners. *Cogent Business & Management, 11*(1), 2320814. https://doi.org/10.1080/23311975.2024.2320814

Falk, M. (2009). High-tech exports and economic growth in industrialized countries. *Applied Economics Letters, 16*(10), 1025-1028. https://doi.org/10.1080/13504850701222228

Freund, C. L., & Weinhold, D. (2004). The effect of the Internet on international trade. *Journal of international economics, 62*(1), 171-189. https://doi.org/10.1016/S0022-1996(03)00059-X

Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of economic growth, 12*, 1-25. https://doi.org/10.1007/s10887-006-9009-4

International Telecommunication Union (ITU). (2009). *Measuring the Information Society: The ICT Development Index*. Geneva: ITU.

International Telecommunication Union (ITU) (2016) Measuring the Information Society Report. Geneva: ITU. Retrieved from https://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2016/MISR2016-w4.pdf

International Telecommunication Union (ITU) (2017) Measuring the Information Society Report. Geneva: ITU. Retrieved from https://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2017.aspx

Jenkins, R., & Edwards, L. (2015). Is China 'crowding out'South African exports of manufactures?. *The European Journal of Development Research, 27*(5), 903-920. https://doi.org/10.1057/ejdr.2014.72

KAbAKLARLI, E. S. R. A., Duran, M. S., & ÜçLER, Y. T. (2018). High-technology exports and economic growth: panel data analysis for selected OECD countriesHigh-technology exports and economic growth: panel data analysis for selected OECD countries. In *Forum Scientiae Oeconomia* (Vol. 6, No. 2018) Issue No. 2: Economic Growth, Innovations and Lobbying, pp. 47-60). Wydawnictwo Naukowe Akademii WSB.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics, 90*(1), 1-44. https://doi.org/10.1016/S0304-4076(98)00023-2

Luong, T. A., & Nguyen, T. H. (2021). The impact of ICT on service trade. *The Singapore Economic Review, 66*(04), 1073-1086. https://doi.org/10.1142/S021759082049003X

Minondo, A. (2010). Exports' quality-adjusted productivity and economic growth. *The Journal of International Trade & Economic Development, 19*(2), 257-287. https://doi.org/10.1080/09638190802573071

Montobbio, F., & Rampa, F. (2005). The impact of technology and structural change on export performance in nine developing countries. *World development, 33*(4), 527-547. https://doi.org/10.1016/j.worlddev.2005.01.001

Nath, H. K., & Liu, L. (2017). Information and communications technology (ICT) and services trade. *Information Economics and Policy, 41*, 81-87. https://doi.org/10.1016/j.infoecopol.2017.06.003

Ozcan, B. (2018). Information and communications technology (ICT) and international trade: evidence from Turkey. *Eurasian Economic Review, 8*, 93-113. https://doi.org/10.1007/s40822-017-0077-x

Özsoy, S., Ergüzel, O. Ş., Ersoy, A. Y., & Saygılı, M. (2022). The impact of digitalization on export of high technology products: A panel data approach. *The Journal of International Trade & Economic Development, 31*(2), 277-298. https://doi.org/10.1080/09638199.2021.1965645

Pesaran, M. H., Shin, Y., & Smith, R. P. (1997). *Pooled estimation of long-run relationships in dynamic heterogeneous panels*.

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American statistical Association, 94*(446), 621-634. https://doi.org/10.1080/01621459.1999.10474156

Portugal-Perez, A., & Wilson, J. S. (2012). Export performance and trade facilitation reform: Hard and soft infrastructure. *World development, 40*(7), 1295-1307. https://doi.org/10.1016/j.worlddev.2011.12.002

Rodrik, D. (2006). What's so special about China's exports?. *China & World Economy, 14*(5), 1-19. https://doi.org/10.1111/j.1749-124X.2006.00038.x

Seyoum, B. (2005). Determinants of levels of high technology exports an empirical investigation. *Journal of Competitiveness Studies, 13*(1), 64.

Srholec, M. (2007). High-tech exports from developing countries: A symptom of technology spurts or statistical illusion?. *Review of world economics, 143*, 227-255. https://doi.org/10.1007/s10290-007-0106-z

Tebaldi, E. (2011). The determinants of high-technology exports: A panel data analysis. *Atlantic Economic Journal, 39*, 343-353. https://doi.org/10.1007/s11293-011-9288-9

United Nations Development Programme (UNDP) (2001) Creating a Development Dynamic: Final Report of the Digital Opportunity Initiative. Retrieved from https://www.markle.org/sites/default/files/doifinalreport.pdf

Veröffentlicht (2014) 'GCC countries dominate the ICT development index', ifg.cc - E-Government News for Germany. Retrieved from http://www.ifg.cc/aktuelles/nachrichten/regionen/562-gcc-gulf-cooperation-council/50057-gcc-countries-dominate-ict-development-index.html

World Bank. (2021) TCdata360 Indicators: Trade Value (TX.VAL). Retrieved from https://tcdata360.worldbank.org/indicators/TX.VAL

Yusuf, M., Hakim, L., Hendra, J., Kamar, K., Idawati, W., Winarso, E., ... & Fahlevi, M. (2023). Blockchain technology for corporate governance and IT governance: A financial perspective. *International Journal of Data & Network Science, 7*(2). https://doi.org/10.5267/j.ijdns.2022.12.018

Zeufack, A. (2001). Export performance in Africa and Asia's manufacturing: Evidence from firm‐level data. *Journal of African Economies, 10*(3), 258-281. https://doi.org/10.1093/jae/10.3.258

Copyrights