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The influence of information and communication technology on trade in developing countries and partners

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ABSTRACT

The widespread use of information and communication technologies (ICT) is evidenced by various devices, systems, and applications that enable organizations and individuals to interact with one another and the digital world. In this study, a comparative analysis framework was employed to evaluate different panel data techniques for the period 1990–2020. The aim is to ensure the robustness of the results and effectively assess ICT modeling in an economic context. The panel techniques found to be relevant and utilized in this study include pooled ordinary least squares (OLS), the fixed effects model (FEM), the random effects model (REM), two-stage least squares (2SLS), fully modified ordinary least squares (FMOLS), dynamic ordinary least squares (DOLS), and robust least squares (ROBUSTLS). The sample comprises 12 trading partners in Pakistan, including both developed and developing economies. The results were consistent and robust across all the techniques employed. Based on these findings, various policy implications can be derived, such as the need for Pakistan to form strategic partnerships with both developed and developing nations to increase the trade component of ICT for rapid growth, because enhancing the ICT-based domestic industry will provide more employment and production opportunities.

IMPACT STATEMENT

This study emphasizes the essential role of information and communication technologies (ICT) in fostering international trade, with a particular focus on Pakistan's interactions with its trading partners. Using a comparative analysis of various panel data techniques over three decades, the research not only verifies the positive impact of ICT advancement on both exports and imports, but also recommends strategic collaborations with technologically advanced nations to enhance Pakistan's trade dynamics. These findings are vital for policymakers, as they suggest that integrating ICT into trade policies can significantly promote economic growth, sustainability, and global competitiveness. By demonstrating the consistent and robust effect of ICT on trade volumes, this study underscores the importance of Pakistan investing in ICT infrastructure and innovation, promoting a digital economy that can lead to increased employment, production opportunities, and sustainable economic practices in line with the Sustainable Development Goals (SDGs).

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1. Introduction

The fourth industrial revolution ushered in a transformative era distinguished by remarkable technological advancements that permeate every aspect of human life, including the economic landscape (Horváth & Szabó, 2019; Saniuk et al., 2023). The core of this revolution lies in the extensive integration of information and communication technologies (ICT), which ushers in a new era of digitization that envelops all sectors of the economy (Ahmad et al., 2023). This remarkable surge in technological progress signifies

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not only a leap forward in innovation, but also underscores the vital role of ICT in driving economic growth, enhancing productivity, and fostering global interconnectedness (Ahmed et al., 2023; Gong et al., 2023). According to the United Nations Development Programme (UNDP), ICT tends to contribute towards the development of the socio-economic framework of an economy as well as the production sector of a particular nation (UNDP, 2001), in terms of the socio-economic framework, recent studies have majorly focused on health, education, and the environment (UNCTAD, 2019), thus leaving a gap towards the trade sector, which in recent years has been increasingly influenced by ICT either in terms of the trade-facilitating functions of ICT or merely ICT-related trade (Stoler, 2003).

ICT has rapidly evolved since the 1990s. Its use has contributed to the improvement of scenarios in which trade information was missing, as well as to the removal of trade barriers and shortening of geographical distances. Hence, ICT has successfully reduced trading expenses, increased trade productivity, and increased trading volumes (Adeleye et al., 2021). Some of the constraints and issues inherent in conventional commerce, such as red tapism, distances involved, and processing time, have been highlighted as a result of the shift to a global data economy; however, they have still not been resolved in the real trading environment (Arvin et al., 2021). Trade based on the use of ICTs has clear benefits and is likely to be a growing trend in the future. Trade is universally recognized as an important driver of economic progress (Fahlevi et al., 2022, 2023; Yusuf et al., 2023). Earnings from exporting services and products to the Global North are regarded as critical sources of foreign cash for developing and least-developed nations, easing balance-of-payment pressures, and creating job opportunities (Luong & Nguyen, 2021).

While technological transfer, international rivalry, and economies of scale seem to be linked to exports, some studies show that imports may also provide advantages. Imports of intermediary products and capital from the Global North in particular have been shown to have a direct beneficial influence on firm performance due to incorporated technological advancement and sophisticated manufacturing processes (Juhász & Steinwender, 2018). It has also been studied by Branstetter et al. (2023)

ICT has enabled advanced service production and activities without any asymmetry in terms of location or information. According to OECD, the wide and rapid increase in ICT has led to the creation of new types of tradable services (OECD, 2007). One of the main drivers of international trade in recent years is ICT (Baldwin & Martin, 1999). With the increasing importance of ICT in recent years, there is greater trade potential for both countries, which are either exporting or importing. According to Christodoulopoulou et al. (2006), ICT tends to enhance and improve the socio-economic development of an economy through contributing significantly towards trade and cooperation.

In the age of globalization, ICT-based developments that enable enterprises to access broader markets, expand their client base, grow in size, and increase profitability have radically impacted and redefined the commercial landscape through sustainable development. Haldar and Sethi (2022) studied its environmental effects, and Khan et al. (2022) and Wen et al. (2022) studied their impact on CO2 emissions. Some growth theories provided a theoretical framework for assessing and evaluating the impact of external technical advancement on economic growth in early empirical research (Rodríguez-Crespo & Martínez-Zarzoso, 2019). High-income nations have experienced technological progress and improvements via R&D, whereas middle- and low-income countries have seen technological operational efficiencies through the implementation of innovations produced in technologically advanced nations (Nath & Liu, 2017). The contribution of 'information and communication technology penetration and deployment' to the socio-economic development of a country is noticed as technological infrastructure advances. The use of telephones per capita enhances growth in GDP per capita, using data from 60 nations over 13 years (Hardy, 1980). ICT is considered a milestone in e-trading because it unlocks the potential for bilateral trade among nations, ultimately accelerating economic growth (Xing, 2018). Foster (2023) studied this in the Chinese context.

Several studies have focused on the effect of information and communication technology on the growth and development of economies; how ICT helps boost the growth of an economy through increased components of ICT in trade has not received due attention. However, when such a context is considered, its prime concern revolves around developed countries, and there is a need to conduct such an evaluation in developing countries. Thus, this research aims to evaluate and analyze the effect of ICT on trade in Pakistan, a developing country, while considering its trading partners, which are a

combination of both developing and developed economies. This study also attempts to fill the gap pertaining to the effect of advanced ICT trade on backward countries when the scope of trade increases with technologically advanced countries, which are the main source of technological inputs in low-to middle-income countries. Furthermore, this study adds value to the existing literature by simultaneously analyzing various panel data estimation procedures to obtain more robust outcomes.

The first research question is whether trading with technologically advanced countries is more beneficial for technologically backward countries in obtaining the technological components needed for economic growth. The second question is whether developing countries have remained successful in using ICT components for their economic growth, which are increasingly available via trade.

i. To evaluate Pakistan's trading partners in terms of ICT component growth over the past two decades.
ii. Comparative analysis of panel techniques on the impact of ICT on trade.

This study introduces significant methodological advancement through the deployment of an exhaustive matrix of ICT components to assess their impact on international trade. Unlike earlier investigations, which typically relied on a limited selection of proxies to measure the influence of ICT, our approach is distinguished by its holistic inclusion of all available ICT components relevant to Pakistan and its trading partners. This comprehensive framework allows for a more nuanced analysis of ICT's multifaceted role in shaping trade dynamics, and ensures a deeper understanding of the specific ways in which various ICT elements contribute to economic interactions. By meticulously compiling and analyzing data across a broad spectrum of ICT factors, this study extends the work of Mattes et al. (2012), specifically tailoring this expanded analysis to the unique context of Pakistan. This innovative approach not only enriches the academic discourse on the nexus between ICT and trade, but also sets a new benchmark for future research in this field, emphasizing the importance of a detailed and inclusive examination of ICT components in understanding their real impact on global trade relations.

This study undertakes a comprehensive evaluation of the methodologies utilized in prior research on the impact of ICT on trade. While previous studies, such as those by Ismail and Omar (2019) and Clarke and Wallsten (2006), have employed limited econometric techniques, our investigation expands the methodological scope. Our study employs a comparative analysis of various panel data estimation techniques, including the Pooled Ordinary Least Squares (OLS), fixed effects, random effects, and two-stage least squares (2SLS) methods, to comprehensively examine the robustness and consistency of the findings across different statistical models.

Our study represents a substantial contribution to the field, as it is not merely an academic exercise but aims to validate the reliability of conclusions regarding ICT's role in trade. By closely examining the consistency of results across various econometric models, our research not only enhances the understanding of the complex relationship between ICT and trade, but also identifies the most effective analytical frameworks for future research in this domain. This comparative analysis elevates the discourse on ICT and trade by highlighting the importance of methodological diversity and precision in capturing the intricate effects of ICT on international trade dynamics. By filling a vital methodological gap, our research not only contributes to the academic community, but also provides policymakers and practitioners with insights into the most reliable models for assessing ICT's economic impact.

The significance of this study transcends mere academic interest and aligns closely with the United Nations' Sustainable Development Goals (SDGs), a global agenda for sustainable development. By examining the role of ICT in economic growth and trade, this study directly contributes to understanding how ICT can be utilized to achieve several SDGs, particularly those related to industry, innovation, and infrastructure (Goal 9); decent work and economic growth (Goal 8); and reduced inequalities (Goal 10). The exploration of ICT's impact on trade and economic development within the framework of this study provides valuable insights into how digital technologies can foster sustainable development, enhance access to information and markets, improve trade efficiency, and ultimately contribute to the eradication of poverty and promotion of prosperity in an inclusive and environmentally sustainable manner. Establishing this linkage underscores the relevance of current research in contributing to the global discourse on leveraging ICT for sustainable development, highlighting its potential to act as a catalyst for achieving the broader objectives of the SDGs.

2. Literature review

2.1. Theoretical foundation

The relationship between ICT and sustainable development, as defined by the United Nations Sustainable Development Goals (SDGs), has gained increasing attention in the realm of economic and social development. Research in this area has primarily focused on examining the effects of ICT on economic growth, productivity, and green trade using metrics such as ICT device proliferation, service subscriptions, and investments in ICT infrastructure (e.g. Bresnahan, 1986; Duggal et al., 2007; Datta & Agarwal, 2004; Hardy, 1980; Jorgenson & Stiroh, 1995; Oliner et al., 1994; Röller & Waverman, 2001; Siegel & Griliches, 1992; Vu, 2011). These studies collectively demonstrate a positive correlation between ICT and economic indicators, emphasizing the role of ICT advancements in promoting economic growth and productivity (Jorgenson & Vu, 2016; Saqib et al., 2023).

The role of ICTs in promoting environmentally sustainable trade practices is a topic of growing interest (Bhujabal et al., 2021), particularly in light of the SDGs. Research suggests that ICTs can play a critical role in enabling economies to transition towards more sustainable trade practices in line with SDG 12, which focuses on ensuring sustainable consumption and production patterns, and SDG 9, which aims to foster innovation and infrastructure development (Chen et al., 2023; Lyu et al., 2023). ICTs can enhance the efficiency of resource use and reduce environmental footprints, promoting economic growth that aligns with sustainability principles. This literature highlights the potential of ICTs to serve as catalysts for sustainable trade practices and contribute to the realization of SDGs.

This theoretical basis therefore highlights the importance of ICT in driving economic growth and productivity while underscoring its crucial role in achieving SDGs. By examining ICT, this body of work presents a roadmap for how digital technologies can be utilized to build economic resilience, promote sustainable industrialization, and ultimately support the broader aims of sustainable development.

2.2. Theoretical framework

Since the Internet is one of the major components of ICT, many initial studies (Albuquerque et al., 2005; Choi, 2010; Greaney, 2005, 2009; Rauch, 2001; Rauch & Trindade, 2002; Swenson, 2004) have emphasized the role played by Internet users in determining the level of trade flows among nations, either bilateral trade or international trade. These studies indicate that Internet penetration (Freund & Weinhold, 2002) or Internet hosts (Freund & Weinhold, 2004) are a major source of enhancing international trade by promoting trade opportunities. However, the gravity model estimation carried out in their studies did not examine the differential impacts of ICTs on exporters and importers.

An increased number of Internet users per hundred people is said to increase overall trade in terms of services (Choi, 2010). Freund and Weinhold (2004) studied the relationship between the Internet and international trade and contended that a significant relationship exists between the two; however, several studies have also confirmed that the impact was not strong uniformly with respect to all regions. Higher Internet adoption in export-oriented countries increases exporters' margins, either extensive or intensive; however, the effect on the extensive margin is often much greater than that on the intensive margin.

Recently, the use and spread of ICT have been thought to be much greater than ever, compared to conventional communication. In the current era of revolution, the role of ICT is significant and important for economic development in terms of trade and growth; however, the role of ICT and the pace of digitalization has led to an increase in privacy and security concerns that need to be dealt with efficiently to benefit from the opportunities created by the growth of the digital world (Meltzer, 2016).

In empirical investigation, international trade refers to the exchange of goods and services across various territories and borders from one end of the world to another. In empirical investigation, ICT is an umbrella term that encompasses various components ranging from radio, cell phones, satellite systems to the Internet, and wireless connections (Rouse, 2005).

Hummels (2007) asserted that ICT can be safely regarded as the defining revolution of the current and future generations. Several studies have been carried out investigated the link between ICT and trade in developed countries. Many researchers and studies have left a gap in studying this relationship in terms of developing economies and how trading with technologically advanced countries could benefit home countries in terms of growth and development.

The last decade has witnessed an increase in the overall ICT trend, especially mobile phone usage, and this trend has been observed in both developed and developing nations. Developing countries have exhibited growth in mobile phone subscriptions from 10 in 2000 to 67.6 in the year 2010, thus allowing future studies to investigate its impact on the notion of trade and development. Khalil et al. (2009) state that this type of growth will lead to the welfare of both first- and third-world nations. The potential of wireless technology is significant (Cardona et al., 2013).

The data for exports and imports were obtained from the World Development Indicators (WDI) for the period 1990–2020 for China. In the current study, we took all the units of the exports and imports either in the form of % of GDP, constant US$ or current US$ and after applying the unit test root, both the variables' exports and imports in current US$ were found to stationary at level as compared to the other two thus providing a rationale to choose this variable in our study. In the formulation of our export and import demand index, the independent and controlled variables are in line with the literature being studied and evaluated. The main explanatory variable in both functions is the ICT Development Index (IDI), which was formulated based on the methodological justification provided by the International Communication Union (ITU, 2009). The rationale behind replicating a new index in our study is the increase in the timeframe for which data were not incorporated in the original IDI developed by the ITU.

'ICT refers to all devices, applications, and systems that allow people, businesses and government to interact with the digital world.' In terms of international trade and technology, the two main theories explaining the importance of ICT (see Table 1) or technology in enhancing international trade are technological gap theory and product cycle theory. Based on these two theories, technology and ICT can enhance trade between two countries by either filling the technology trade gap or innovating product cycles.

The GDP per capita growth rate is a measure of the amount earned by an individual in a geographical nation. Unlike some studies (Vemuri & Siddiqi, 2009), this study uses GDP per capita growth in the estimation technique to minimize and avoid the possibility of a regression problem that may arise due to the presence of unit roots in the data mining task for the variables being considered in

Table 1. Summary of E-indexes used to measure ICT adoption.

Index	Measure	Author/organization
Information Society Index	'Index by which all countries are ranked according to their ability to access and absorb ICT'	IDC
E-Government Readiness Index	'Measures the capacity of governments to develop & implement the e-government services'	UN
Knowledge Economy Index	'A broad measure of the overall level of preparedness of a country or region for the knowledge economy'	World bank institute
E-Government Development Index	'Weighted average of normalized scores on the three most important dimensions of e-Government; Online service index, Telecommunication Infrastructure Index, Human Capital Index'	UNDESA
ICT Development Index	'To monitor and compare developments in ICT between countries and over time'	ITU
Digital Access Index	'Measures the overall ability of individuals in a country to access and use ICT'	ITU
Technology Achievement Index	'Measures the countries' skills to participate in the network age'	UNDP
Networked Readiness Index	'Measure the degree of readiness of countries to exploit opportunities offered by ICT'	WEF
Digital Opportunity Index	'Measures the ICT penetration of households and individuals'	ITU
ICT Opportunity Index	'Tool to track the digital divide'	ITU
ICT Diffusion Index	'Weights the distribution of broadband subscribers, personal computers, mobile phones, Internet users, and international Internet bandwidth by economic output'	UNCTAD
Global Innovation Index	'Capture the multi-dimensional facets of innovation'	INSEAD
Infostates	'To measure the Digital Divide'	ORBICOM

the study. The income theory of money is best suited to per-capita income. The objective of this study is to explore the economic performance of the country. The focus of this theory is to identify the rates of inflation and unemployment, which are directly related to per capita GDP (Barton, 1974). Per capita GDP growth is vital for a country because if the income of people is higher than the economic conditions, it will ultimately lead to an increase in the trading activities of the nation. An increase in per capita growth is said to improve economic growth, which in turn improves the standard of living. Such an improvement also tends to increase the level of import demand in the economy; however, its effect on exports is unclear. On the one hand, it could be said that due to the rise in economic growth, there is also an increase in the notion of production that may level up the exports of a country; however, it can also be stated that the increase in production can be compensated by the increase in domestic demand as compared to external demand, which may offset exports in the economy.

Tariffs are charges imposed by the government on a country's imports and exports. However, the tariffs are normally charged on imports but are paid by the home country in the form of high prices. The theory of comparative advantage is applied to tariffs because their main purpose is to discourage imports from the country. Comparative advantage theory posits that tariff-free trade is good from a business perspective, but import tariffs allow the government to discourage imports and improve the country's export levels (Hunt & Morgan, 1995).

The currency value of one country in terms of another is referred to as the exchange rate. The official exchange rate is used in both demand functions in the current study because it is thought to be one of the leading indicators influencing a country's export and import levels. An increase in the exchange rate tends to make domestic goods and services cheaper than goods from other countries, resulting in an increase in local competitiveness.

2.2.1. ICT Development Index

In 2009, the International Commission Union (ITU) formulated the Information and Communication Development Index (IDI) with the aim of tracking and tracing developments in the digital world and evaluating the progress of countries in becoming more technologically advanced and informative. The IDI is a detailed and comprehensive index that aggregates 11 components covering the ICT context into one index, which is treated as a benchmark for monitoring information and communication developments across various countries. To access and measure the three main components of ICT, the ITU proposes a combination of sub-indexes mainly focused on ICT access, skills, and usage, which are then aggregated to derive an overall ICT index, also known as ICT development.

According to the ITU (2009), ICT development in a country can be divided into three stages.

- 'Stage 1: ICT Readiness reflecting the level of networked infrastructure and access to ICTs.'
- 'Stage 2: ICT Intensity reflecting the level of use of ICTs in the society.'
- 'Stage 3: ICT impact reflecting the result/outcome of efficient and effective ICT use.'

Based on the conceptual framework (see Figure 1), to evaluate all three stages, a composite index is constructed, known as the IDI by ITU (2009), which suggests that there should be a further division of IDI into three sub-indices. In this study, the following indicators in each sub-index were considered because of the availability of data for the countries being studied.

- In the 'access' sub-index, the indicators used to assess the access to ICT includes the 'fixed telephone subscriptions per 100 people, the mobile cellular subscriptions per 100 people and the international internet bandwidth. The data for these variables will be taken from world development indicators because of the availability of data for the time period of our study.
- In the 'use' sub-index, the indicators used to measure the intensity of ICT includes the 'internet users and fixed broadband internet subscriptions per 100 people.' The data for these variables will be taken from world development indicators because of the availability of data for the time period of our study.

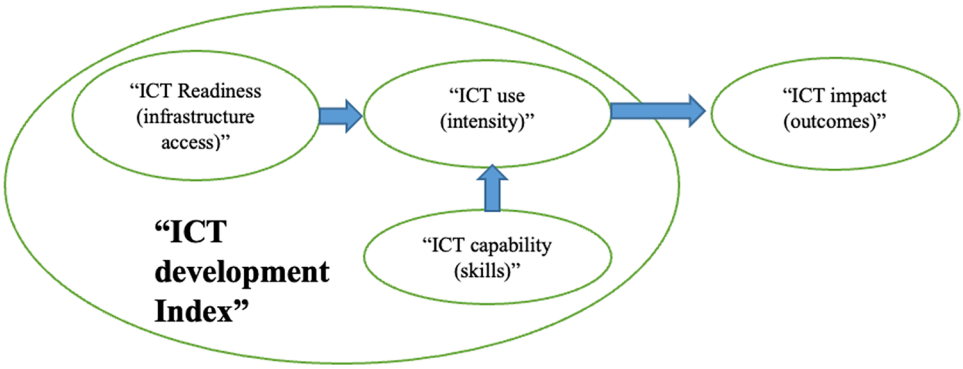

Figure 1. Three stages in the evolution towards an information society.
Source: International Telecommunication Union (ITU).

- In the 'skills' sub-index, the indicators used to capture the capability of ICT include the 'gross enrollment ratio at secondary and tertiary levels.' The data for these variables will be taken from world development indicators because of the availability of data for the time period of our study.

$$"ICT = f\begin{pmatrix} fixed\,telephone\,subscriptions, mobile\,cellular\,subscriptions, international\,Internet \\ bandwidth\,per\,Internet\,user, households\,with\,a\,computer, and\,households\,with\,Internet\,access, \\ internet\,users, fixed\,broadband\,subscriptions, mobile\,broadband\,subscriptions, adult\,literacy\,rate, \\ gross\,enrollment\,ratio \end{pmatrix}"$$

2.2.2. ICT access indicators

The components or indicators in the 'ICT access' sub-index provide a measure of ICT infrastructure and access to basic ICTs. The data for the indicators in this sub-index were derived from the WDI for 1990–2020.

2.2.2.1. Fixed telephone lines per 100 inhabitants. According to World bank, *'fixed telephone subscriptions refer to the sum of active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones.'*

2.2.2.2. Mobile cellular telephone subscriptions per 100 inhabitants. According to the World Bank, *'mobile cellular subscriptions refer to the subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology.'*

2.2.2.3. International Internet bandwidth (bit/s) per Internet user. According to ITU, *'international internet bandwidth refers to the total used capacity of international Internet bandwidth, in megabits per second (Mbit/s).'*

2.2.3. ICT use indicators

The components included in the 'ICT use' sub-index provide a measure of ICT usage. The data for the indicators included in this sub-index were retrieved from the World Development Indicators (WDI) for 1990–2020.

2.2.3.1. Internet users per 100 inhabitants. According to the World Bank, *'Internet users are the total number of Internet users from any region or locality. In many countries, the data on the internet users is taken through household surveys, however, in developed economies, the data on this variable is directly provided by the National statistics offices (NSOs).'*

2.2.3.2. Fixed broadband Internet subscribers per 100 inhabitants. According to World Bank, *'fixed broadband internet subscription refers to subscription to the high-speed internet access to the public.'*

2.2.3.3. Mobile broadband subscriptions per 100 inhabitants. According to the World Bank, *'Mobile broadband subscriptions refer to the subscriptions of mobile advertising data speeds of 256 kbit/s or greater'*

2.2.4. ICT skills indicators

The components included in the 'ICT skills' sub-index provide a measure of the skill set required in terms of basic information and communication technologies. The data for the indicators included in this sub-index were retrieved from the World Development Indicators (WDI) for 1990–2020.

2.2.4.1. Adult literacy rate. UIS defines adult literacy rate as *'the rate is defined as the percentage of population aged 15 years and over who can both read and write with understanding a short simple statement on his/her everyday life.'*

2.2.4.2. Gross enrollment ratio (secondary and tertiary level). UIS defines the gross enrollment ratio as '*the total enrollment in a specific level of education, regardless of age, expressed as a percentage of the eligible official school-age population corresponding to the same level of education in a given school-year.'*

Since the current study is being carried out for the period from 1990 to 2020, data on the international telecommunication union database are not available for the full period; thus, the IDI index construction will be replicated by including the time frame missed by the ITU in their overall construction of IDI.

The ICT sub-indices, including ICT access, ICT use, and ICT skills index, were computed using the same methodology as the International Communication Union (ITU) used to curate the information and communication development index (see Table 2). In the first step, the average and standard deviation were taken for all items in each group, which were then normalized using the reference value, which was calculated as follows:

$$Referencevalue = Mean + 2^{*}\left(Stdv\right)$$

Finally, to convert the final ICT sub-indices into one index, known as the ICT development index (IDI), this study uses the system of weights used by the International Communication Union (ITU) through the Principal Component Analysis (PCA) method. On the one hand, the ICT access index and ICT use index are given 40% weighting, whereas on the other hand, the ICT skills index is given 20% weighting (see Table 3).

Table 2. Reference values obtained through statistical procedures.

Country	ICT access			ICT use		ICT skills	
	Fixed Telephone Subscriptions per 100 inhabitants	Mobile Cellular Subscriptions per 100 inhabitants	International internet bandwidth(bit/s) per internet users	Percentage of individuals using internet	Fixed-broadband subscriptions per 100 inhabitants	Secondary gross enrollment ratio	Tertiary gross enrollment ratio
China	4.503945	8.486944	22.69471273	69.5154	4.717612	114.685	56.989555
Hong Kong	4.220251	7.272077	24.37711343	115.746	4.907619	115.6203	93.884581
UAE	3.561657	7.066067	20.19836887	122.021	4.505384	125.6064	57.247469
UK	4.122944	6.643394	23.17327562	129.465	5.332271	127.2098	73.803986
USA	4.409697	6.158995	23.2510588	116.011	4.986517	101.2412	91.037995
Japan	4.011173	6.878227	20.23497791	127.327	4.93776	107.6079	92.151827
Malaysia	2.809439	3.415511	14.48697873	39.8889	2.239938	76.62331	28.314307
India	1.808069	7.728936	22.39701893	25.2635	1.6696	82.76573	32.318649
Germany	4.335863	7.18069	19.20399084	123.158	5.36524	106.333	77.602784
Italy	3.951148	7.371733	14.53184754	86.5465	4.862488	111.2555	79.793409
Spain	3.865332	7.605932	14.1637499	109.795	5.011984	130.8282	102.50572
Netherlands	4.167596	7.205635	14.84054289	133.335	5.283195	139.8593	90.660311
Pakistan	1.510691	8.001449	18.9342263	16.4625	1.648043	47.87871	13.164504

'Notes: the reference value: mean + 2 * standard deviation'.
'*Source*: Computed by the author based on the method explained in ITU (2009)'.

Table 3. The indicators and weight in the ICT Development Index.

The indicators and weight in the ICT Development Index	
	Weight
ICT access (A)	
'Fixed-telephone subscriptions per 100 inhabitants' (ai)	Log(x)*0.33/Refvalue
'Mobile/cellular telephone subscriptions per 100 inhabitants' (aii)	Log(x)*0.33/Refvalue
'International internet bandwidth (bit/s) per internet user' (aiii)	Log(x)*0.33/ Refvalue
ICT Access Sub-Index (A) = (ai + aii + aiii)	
ICT use (B)	
'Percentage of individuals using the internet' (bi)	x*0.5/ Refvalue
'Fixed-broadband subscriptions per 100 inhabitants' (bii)	Log(x)*0.5/ Refvalue
ICT use Sub-Index (B) = (bi + bii)	
ICT skills (C)	
'Secondary gross enrollment ratio' (ci)	x/2/(Refvalue)
'Tertiary gross enrollment ratio' (cii)	x/2/(Refvalue)
ICT skills Sub-Index (C) = (ci + cii)	
Aggregated Index (IDI): (A)*4 + (B)*4 + (C)*2	

2.3. Empirical evidence and literature gaps

This section highlighting key empirical studies and identifying gaps in the literature (see Appendix B).

2.3.1. ICT and service trade dynamics

Salmani et al. (2013) studied how the Internet affected trade in terms of services using an unbalanced panel data approach and concluded that Internet users per hundred people had a significantly direct effect on service trade in developing economies. Similarly, a study conducted by Bojnec and Fertö (2009) showed how the Internet per hundred people enhanced and stimulated exports of manufactured goods among OECD countries. The Internet greatly influences trade between countries because it minimizes the cost to both buyers and sellers in terms of searching (Biswas & Kennedy, 2016).

A study conducted by Kurihara and Fukushima (2013) emphasized how the prevalence of the Internet directly influenced international trade in developing nations in Asia. The authors suggest that economies, especially developing ones, need to implement policies to smoothen and facilitate ICT investment to promote and enhance trade among countries, while also effectively and efficiently enhancing economic growth. Kurniawati (2022) conducted a similar study in an Asian country. The presence of the Internet enhances and improves export performance in developing countries (Clarke & Wallsten, 2006).

Timmis (2012) suggested through a panel data estimation that countries, either developing or developed, tend to trade more with those who exhibit increased rates of Internet use, broadband subscriptions, and fixed line connections; however, when accounting for multilateral resistance, the study was unable to evaluate the consequences of information and communication technologies on the importer or exporter separately.

2.3.2. ICT infrastructure and trade facilitation

Ismail and Omar (2019) examined how ICT impacted the phenomenon of trade in five ASEAN countries by using Hausman, fixed effect, and random effect models. The authors suggested that the Internet, mobile broadband, and mobile cellular users had a large and favorable impact on trade facilitation and, thus, the overall growth of a nation. The study revealed that although the use of ICT services is based on cost, ICT development helps to effectively execute financial foundations in financial markets by promoting trade.

Lee (2012) studied the relationship between internet and international trade by using the data from OECD countries and employing a gravity model. The study concluded that the Internet played a major role in the network effect for the manufacturing and service sectors, while migration played a significant role in the manufacturing sector only.

Abeliansky and Hilbert (2014) investigated the differential effects of ICT quality and quantity on international trade. The study concludes that a positive relationship exists between the quality and quantity of information, communication technology, and exports. The study also showed that in the case of developing economies, the quality of data speed is more important than ICT subscriptions.

In the case of Malaysia and her trading partners, Ahmad et al. (2011) studied and evaluated the role of 'information and communication technology infrastructure' on the notion of trade. The results revealed

that some ICT components, such as mobile-cellular subscriptions, fixed telephone subscriptions, Internet users, and personal computers, increased the value and intensity of trade between Malaysia and its trading partners. The study asserted that for an organization to be efficient and effective, it must have a modern information and communication infrastructure to assist operations on a daily basis. It also contributes to the overall welfare by minimizing information asymmetry. Additionally, owing to advances in ICTs, delays in the acquisition and transmission of information have been reduced (Nath & Liu, 2017).

2.3.3. ICT and trade theoretical models

Using international trade theoretical models, some studies have found that countries that show and exhibit higher Internet use tend to trade more, indicating that the existence of mutual Internet infrastructure between the two countries augments their trade (Demirkan et al., 2009; Rodríguez-Crespo & Martínez-Zarzoso, 2019). In this era of globalization, the Internet is used by the majority of people in a variety of fields, including education and trade (Tay, 2015). A recent study by Gnangnon and Iyer (2017) examined whether the adoption of the Internet raises the level of commercial service trade value. After estimating a two-step GMM technique, the authors posit a positive stance on the above hypothesis.

Along with the increase in the trend of the Internet, there has been an increase in issues related to analytics and big data that not only disrupted the old methods of business, but also increased the importance of new skills and technologies needed to boost trading practices among countries (Baesens et al., 2016; Drnevich & Croson, 2013; Lyytinen & Rose, 2003). Putri and Hayati (2021) emphasized that Internet users tend to positively and significantly affect export performance, while fixed telephone subscriptions have an inverse impact on the notion of international trade. In contrast, Chung et al. (2013) showed that in the case of APEC countries, telephone had a positive and significant impact on vegetable and fruit trade from 1997 to 2006.

Apart from the Internet, few researchers have explored the effects of mobile or telephone usage on the notion of trade. Boateng (2018) examined the case of Ghana, where traders, especially women traders, used mobile phones to improve and enhance trading information management. Asongu (2015) provides empirical data on the income-redistributive effects of mobile phone penetration in 52 African nations in the qualitative and theoretical literature. The two empirical methods used by the authors are OLS and 2SLS.

Vemuri and Siddiqi (2009) estimate the influence of ICT infrastructure and broadband penetration on world trade in 64 countries for the time period from 1985 to 2005. The study's results showed a significant relationship between the two variables, indicating how an increase in the internet by10% led to a 2% increase in trade on a bilateral level, while Choi (2010) found that doubling the Internet led to a 2–4% increase in the exports of 151 countries between 1990 and 2006. According to a study conducted by Liu and Nath (2013), Internet subscriptions and hosts played an important role in the trade performance of 40 emerging nations from 1995 to 2010.

While some studies mainly focused on Internet use as a means to enhance trade among trading partners, many studies have shown how several countries tend to divert their focus on trading more with developed or developing countries, which are from the beginning more enhanced and invested in Internet penetration (Clarke & Wallsten, 2006). The higher the level of ICT development in both trading partners, the higher is the trade flow between both services and goods (Tee et al., 2020).

On the other hand, many researchers have found that even when the spectrum of the studies is broad, there is always one variable from the list of ICT components that plays an important or crucial role in enhancing the phenomenon of international trade. Chu and Guo (2019) broadly investigated the effect of ICT on international trade between China and ASEAN countries and concluded that cellular phones played a major role in causing a positively significant change in trade level between ASEAN and PRC. By contrast, Kneller and Timmis (2016) found that broadband use had a huge impact on the firm-extensive margin of UK service exports.

Tang (2006) applied the fixed-effect model approach to investigate how the use of various modes of telecommunication affects US imports of differentiated goods. According to the study, the adoption of fixed-line telephones, mobile phones, and Internet connections in export markets has a noticeable effect on US imports of differentiated products, showing that a 10% increase in online adoption by exporters improves exports of goods to the US by 1%. Clarke and Wallsten (2006) discovered that an increase in

Internet penetration encouraged trade flows from developing to developed nations; however, there was no noticeable impact when trade flowed from developed to developing nations. Xing (2018) argues that the productive and efficient use of ICTs, along with advanced Internet services and servers, holds an important position in the enhancement and advancement of the e-commerce potential of developed and developing economies.

Tay (2018) studied the role of ICT in bilateral service trade using two sets of determinants: trade and ICT. Similarly, the study employed two estimation techniques, the fixed effect model and the pooled OLS method, to study the impact of information and communication technology (ICT) on service trade for the time period 2000–2013 in the USA and 34 partnering countries. It was concluded that some of the ICT determinants, including fixed broadband and fixed telephone, had the most notable effect on service trade compared to mobile cellular phones, which was found to be insignificant in enhancing or broadening service trade (exports or imports). However, Rodriguez-Crespo et al. (2021) state that mobile phones play a greater role in countries that import from high-to low- or middle-income countries.

Most studies state that first-world countries or economies rely heavily on ICT to boost exports of goods and services. Tay (2017) concluded that first-world countries, especially the USA, tend to rely more on ICT for exports of goods and services than on imports. A study conducted by Bai (2019) also concluded that, in the United States, an increase or boost in ICT stimulates exports. Similarly, the impact of one of the major components of ICT, the Internet, tends to be greater on the export of ICT-enabled services than non-ICT services. However, there is still a discrepancy over whether the rise in Internet use weakens the negative role of physical distance in the broad spectrum of international trade.

Mattes et al. (2012) empirically investigated the linkage between information and communication technology and trade flow by evaluating the European Union (EU) and its trading partners. Using a Specific ICT Development Index. The study specifically examined how trade between two partners is affected if both pursue high levels of ICT endowments and found that trade was enhanced and impoverished if both trading partners revealed a higher level of ICT presence, thus supporting the expected hypothesis of the study. Similarly, the results of the estimation techniques being carried out also contribute to the fact that the effects of ICT on trade tend to be far less in developing economies than in developed economies. On the other hand, a dynamic panel data model by using a similar information and communication development index, which was previously used by Mattes et al. (2012), and concluded that ICT development had a limited effect on service trade between the 49 countries from to 2000–2013.

Ismail and Omar (2019) evaluates the connection between digital trade facilitation and bilateral trade in Asian countries. This study attempts to explain the significance of using digital infrastructure to facilitate trade between economies. Using fixed telephone, cellular, and broadband subscriptions, the study concludes that the higher the use of the infrastructure of the digital world, the higher the trade flow in Asian economies. According to Zhou et al. (2022), broadband impacts exports through indirect channels. Natalegawa and Poling (2022) focused mainly on the southeastern region. Chu and Guo (2019) examined the effects of ICT on regional and global economic development.

2.3.4. Digital infrastructure and trade expansion

Özsoy et al. (2022) evaluated the effects of ICT and the trend of digitalization on exports of essential and luxury goods as well as services. The study concluded that the pace of digitalization plays a significant role in accessing and seeking new information, which ultimately leads to an increase in technological exports and the overall efficiency of the economies. In short, innovation can be viewed as an essential tool for influencing the product quality that countries export (Gokmen & Turen, 2013; Sandu & Ciocanel, 2014; Tebaldi, 2011).

Mathews et al. (2015) determined whether the use of information and communication plays a role in augmenting trade capability and the availability of export information. According to this study, ICT seems to have a notable effect on export information and its availability, resulting in the creation of relationships in business networks and the expansion of export markets. Information and communication technologies can improve supply chain operations by facilitating and empowering existing and new businesses (Walsham, 2017; Wang & Choi, 2019; Yeo & Grant, 2019).

Yushkova (2014) used the Internet usage index to investigate the role of the Internet on the total number of exports of goods in 40 countries for the year 2011. The study concludes that business entities that extensively use the Internet positively affect export flows. The use of modern ICT and the adoption of e-commerce applications tends to enhance and improve trade at various levels in both developed and developing economies (Xing, 2018). Wang and Choi (2019) carried out an investigation to determine how ICT affected the trade of BRICS countries for the time period from 2000 to 2016 using panel data. The final findings show how ICT enhances and promotes international trade by lowering information search costs, thus concluding that the digital economy positively affects trade.

Cano and Baena (2015) showed how the use of ICT plays a significant part in the enhancement of international processes; thus, it is important to increase the use of various ICT applications and components in order to carry out international sales contracts for efficient results and outcomes. However, the presence of ICT must also be complemented by various skillsets and traits, that is, training and expertise, along with confidence and attitude, to achieve desirable results. Some studies have explored the impact of 'sT on the trade of specific goods, such as steel (Shemayev, 2014), fruits, and vegetables (Thiemann et al., 2012).

Manickam et al. (2021) conducted a study that studied how ICT impacted trade in the ASEAN economies through a static panel model estimation by taking some of the ICT components, including mobile cellular, fixed broadband, and fixed telephone subscriptions along with the users of the Internet, thus leaving a gap for further studies to take into account a wide variety of ICT variables for a broader estimation and reflection in the future of ICT on international trade. The findings of the study show that the advancement of ICT seemed to have a notable effect on the process of trade, especially during the 2020 pandemic, which shaped the recent digital economy; thus, it is essential for the government today to consider ICT policies and their implementation in order to safeguard and improve long-term expansion in terms of exports and imports.

Aryani and Andari (2021) conducted an analysis based on quantitative data and static panel data, along with a gravity model approach, to gauge the impact of ICT on the trade of ASEAN countries from the trading partners of Indonesia from 2010 to 2018. The results of the study conclude that ICT favorably leads to the enhancement and development of trade value from Indonesia to its trading partners, specifically ASEAN.

3. Methodology

3.1. Data sources

Table 4 systematically lists and defines the variables and indicators used in the research, providing clarity on what each represents and where the data were sourced. Table 4 includes key economic and technological metrics, such as exports, imports, exchange rates, tariffs, GDP, and various measures of ICT development, such as internet usage and mobile subscriptions.

3.2. Description of the variables

In this study, a comprehensive examination of Pakistan's trading partners is undertaken, drawing upon multiple sources, such as trading economies and world population reviews. The primary objective of this study is to scrutinize the relationship between Pakistan and its trading partners, with a particular focus on the role of ICT in international trade. To this end, a total of twelve highly technologically advanced countries were chosen from a vast array of Pakistan's trading partners. The selection of these countries was based on the information obtained from Fabuleas.com. The sample for this study, comprising 12 highly technologically advanced countries among Pakistan's trading partners, was strategically chosen to provide a robust examination of the impact of ICT on international trade dynamics. This decision was made in light of several compelling reasons that enhanced the study's relevance and potential for yielding insightful findings.

This study intends to focus on technologically advanced countries to identify the most profound effects of ICTs on trade practices and outcomes. These nations are at the forefront of digital innovation

Table 4. Variable definition and data sources.

Variables/indicators	Unit/Proxy	Definition	Sources
Exports	'Exports of goods and services (current US$)'	'The goods and services which are produced in one country and is sold to another country'	'World development indicators'
Imports	'Imports of goods and services (current US$)'	'The goods and services which are produced in the foreign country and are sold in the resident country'	'World development indicators'
Exchange Rate	• 'Real effective exchange rate index (2010 = 100)' • 'Official exchange rate (LCU per US$, period average)'	'The value of the currency of a specific country in terms of another country'	'World development indicators and FRED'
Tariffs	'*Tariff* rate, applied, weighted mean, all products (%)'	'A duty or tax which is paid on a certain class of exports or imports'	'World development indicators'
Gross Domestic Product	'GDP (constant 2015 US$)'	'Refers to the monetary value of all finished goods and services made within a country during a specific period.'	'World development indicators'
Per capita income	'GDP per capita (constant 2015 US$)'	'Measure of the amount of money earned per person in a nation.'	'World development indicators'
Inflation	'Consumer price index (2010 = 100)'	'Refers to the increase in the prices over a given period of time.'	'World development indicators'
Gross Fixed Capital Formation	'Gross capital formation (% of GDP)'	'Comprises all the fixed assets minus the disposals by resident producers.'	'World development indicators'
Fixed Telephone subscriptions	'Fixed telephone subscriptions (per 100 people)'	'Refers to the sum of active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones.'	'World development indicators'
Mobile Cellular subscriptions	'Mobile cellular subscriptions (per 100 people)'	'Subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology.'	'World development indicators'
Fixed broadband subscriptions	'Fixed broadband subscriptions (per 100 people)'	'Subscription to the high-speed internet access to the public.'	'World development indicators'
Mobile cellular subscriptions	'Mobile cellular subscriptions (per 100 people)'	'Subscriptions of mobile advertising data speeds of 256 kbit/s or greater.'	'World development indicators'
International bandwidth	'International bandwidth; in Mbit/s'	'The transmission or rate of data from one part of world to the other.'	'ITU'
Internet users	'Individuals using the Internet (% of population)'	'The total number of users of the internet from any region or locality.'	'World development indicators'
Secondary school enrollment	'School enrollment, secondary (% gross)'	'The percentage of the total enrollment in the in secondary education institutions to the population'	'World development indicators'
Tertiary school enrollment	'School enrollment, tertiary (% gross)'	'The percentage of the total enrollment, in post-secondary institutions to the population.'	'World development indicators'

and infrastructure development, making them ideal subjects for understanding the future of trade digitization and its potential advantages and difficulties. These countries' technological advancement is likely to have a significant impact on their trade policies, practices, and efficiency, making them an important case study for analyzing the role of ICTs in enhancing trade performance. The inclusion of these countries provides a valuable perspective on how Pakistan can leverage ICTs to enhance trade and economic growth. By examining trade dynamics with countries that have successfully integrated ICTs into their economies, this study identifies the best practices, innovative technologies, and policy measures that Pakistan could adopt to enhance its trade infrastructure and outcomes. This comparative analysis is essential for developing strategies that can help Pakistan bridge the digital divide and harness the potential of ICTs for economic development.

To carry out an extensive empirical investigation, the data are gathered from some of the most authentic and important sources known as the 'World Development Indicators (WDI), Federal Reserve

Economic Data (FRED), and United Nations Conference on Trade and Development (UNCTAD).' We focus on the last 30 years, because a significant change in ICT has mainly occurred in Pakistan over the last three decades. To evaluate the export and import demand functions separately, two separate models were developed, whose data were retrieved from both sources mentioned above. The data on exports, imports, exchange rate, per capita income, and all relevant ICT indicators were taken from the World Development Indicators. The rationale for choosing WDI for the data of ICT indicators instead of ITU, which compiles the ICT indicators database, is the unavailability of data prior to 2000. In this study, we attempted to capture the effect of ICTs on trade for the period 1990–2020, for a total of 30 years.

Finding a particular measure of ICT that captures the wide purpose of the technology in different sectors, especially trade, is nearly impossible, and many previous studies have taken into consideration the component or the other to evaluate its relationship with trade (Choi, 2010; Clarke & Wallsten, 2006; Freund & Weinhold, 2002, 2004; Vemuri & Siddiqi, 2009). Therefore, in this study, an index of all ICT components ranging from fixed telephone subscriptions to Internet users will be developed, whose impact will then be seen on the demand functions of exports and imports.

3.3. Empirical model

Following the model used by Liu and Nath (2013), this model estimates two sets of equations: where the former will be referred to as the export demand function, while the latter will be referred to as the import demand function. However, on the contrary, this study formulates an ICT matrix to evaluate its impact on exports and imports, instead of taking one ICT indicator at a time, as taken by Liu and Nath (2013), who evaluated six separate models with different ICT indicators each time. In our study, ICT was a matrix of all variables covered by information and communication.

In the current study, the export demand function represents the functional linkage between exports and a list of variables, including gross capital formation, per capita income growth, official exchange rate, real effective exchange rate, tariff, trade balance, and the matrix of ICT indicators, in contrast to Liu and Nath (2013), who estimated six different models for each ICT variable.

$$"Exports_t = \alpha + \beta_1 IDI_t + \beta_2 GCF\_PCGDP_t + \beta_3 GRTH\_PCGDP_t + \beta_4 OER_t + \beta_5 REER_t + \beta_6 TARIFF_t + \mu"$$

In the second stage, the current study forms a functional relationship between imports and a list of variables, including Real GDP, official exchange rate, per capita GDP growth, trade balance, tariff, gross fixed capital formation, consumer price index (CPI), and the matrix of ICT indicators, in contrast to Liu and Nath (2013), who estimated six different models with each ICT variable.

$$"Imports_t = \alpha + \beta_1 IDI_t + \beta_2 GCF\_PCGDP_t + \beta_3 GRTH\_PCGDP_t + \beta_4 OER_t + \beta_5 EALGDP_t + \beta_6 TARIFF_t + \beta_7 CPI_t + \mu"$$

4. Result and discussion

4.1. Descriptive analysis of export demand function

This section analyzes the descriptive statistics of the export-demand function. To obtain a better picture of how the ICT development index affects exports of goods and services, this study first evaluated the nature of the data. The descriptive statistics for the export demand function can be evaluated and analyzed (Table 5). Owing to the large values of our variables, the data on most of them, excluding the indices, are converted to their logarithmic form.

The table summarizes the mean, median, maximum, and minimum values of the variables. The smaller the mean of the variables included in the analysis, the higher is the accuracy of the model (see Table 6).

4.1.1. Unit test root for export demand function

To determine whether the variables in the model are stationary, Levin, Lin and Chu t, lm, Pesaran and Shin W stat, augmented Dickey–Fuller (ADF) – Fisher Chi Square, PP – Fisher Chi Square, and Hadri Z-stat unit root tests were conducted (see Appendix A).

Table 5. Descriptive statistics for export demand function.

Variables	Mean	Median	Maximum	Minimum
EXPORTS	26.06398	27.37298	28.63285	24.61773
IDI	4.972492	5.211605	3.700862	3.513723
GCF_PCGDP	3.698720	3.700862	3.842890	3.513727
GRTH_PCGDP	2.049996	2.094884	2.612700	0.749775
OER	1.958598	1.932736	2.153939	1.565112
REER	99.46759	96.76413	129.9704	70.52476
TARIFF	2.128490	1.945678	3.502802	0.000000

Table 6. Covariance matrix of export demand function.

	EXPORTS	IDI	GCF_PCGDP	GRTH_PCGDP	OER	REER	TARIFF
EXPORTS	28.20482	1.599678	−0.1595	0.205287	−5.55695	8.8517	−0.58328
IDI	1.599678	5.657746	−0.1047	−0.00472	−1.5688	−1.84695	−1.22984
GCF_PCGDP	−0.1595	−0.1047	0.065926	0.027651	0.108686	−0.13017	0.047053
GRTH_PCGDP	0.205287	−0.00472	0.027651	0.350042	−0.00637	−1.198	0.022442
OER	−5.55695	−1.5688	0.108686	−0.00637	3.886528	−2.78653	0.72807
REER	8.8517	−1.84695	−0.13017	−1.198	−2.78653	178.2493	−1.63569
TARIFF	−0.58328	−1.22984	0.047053	0.022442	0.72807	−1.63569	0.757317

Table 7. Unit root test-summary statistics for export demand function.

Variable	Levin, Lin & Chu t	Im, Pesaran & Shin W-stat	ADF – Fisher Chi Square	PP – Fisher Chi Square	Hadri-Z-stat	Stationarity
Null Hypothesis: Panels contain unit roots						
Exports	2265.54***	−2.39757***	46.6360***	49.1626***	10.8352***	I(0)
IDI	−8.81536***	−5.90941***	89.2526***	235.539***	13.2696***	I(0)
GCF_PCGDP	−2.19835**	−1.87478**	35.5465*	38.3160*	6.79773***	I(0)
GRTH_PCGDP	6.69622	−3.11522***	61.0185***	91.5075***	1.84878***	I(0)
OER	−1.75262**	−1.47931*	32.7000	30.2108	8.65133***	I(0)
REER	−2.12396**	−1.97119**	40.2748**	31.5420	6.50965***	I(0)
TARIFF	−2.65107***	−0.15216	25.5956	47.8961***	11.1823***	I(0)

Note: (*) indicates significance at 10%, (**) indicates significance at 5%, (***) indicates significance at 1%.
Source: Author's analysis.

Table 8. Kao cointegration test for export demand function.

	Statistic	*p* value
Modified Dickey-Fuller t	−3.9592	0.0000***
Dickey-Fuller t	−3.7076	0.0001***
Augmented Dickey-Fuller t	−2.2620	0.0118**

Note: (*) and (**) show a 5% significance level; (***) indicates significance at the 10%, 5%, and 1% levels, respectively.
Source: Authors' own computations.

DECISION RULE: If the probability values of three out of the five tests are statistically significant at 1%, 5%, or 10%, the variables are stationary; otherwise, they are not stationary.

From the unit root results in Table 7, it can be summarized that the variables were stationary in order I(0).

4.1.2. Long run relationship test for export demand function

The cointegration test was carried out to examine and evaluate the relationships among the variables in the long run using the Kao cointegration test (see Table 8).

Decision Rule: We will not accept the null hypothesis in absolute terms if the likelihood ratio of the variable is greater than the critical value.

4.1.3. Short run relationship test for export demand function

To determine the connection between the explanatory variables in the short run, a Wald test was conducted, the results of which are summarized in Table 9.

Table 9. Short run results (Wald test results) for export demand function.

Variable	F-statistic	*p* value	Conclusion
IDI	0.201246	0.6540	Insignificant
GCF_PCGDP	0.529510	0.4672	Insignificant
GRTH_PCGDP	3.150430	0.0767*	Significant
OER	144.5698	0.0000***	Significant
REER	4.971866	0.0263**	Significant
TARIFF	6.839732	0.0093***	Significant

Note: (*) and (**) show a 5% significance level; (***) indicates significance at the 10%, 5%, and 1% levels, respectively.
Source: Authors' own computations.

Table 10. Descriptive statistics for import demand function.

Variables	Mean	Median	Maximum	Minimum
IMPORT	26.29777	27.19826	28.57263	24.37293
IDI	4.972492	5.211605	8.542679	−0.791823
GCF_PCGDP	3.698720	3.700862	3.842890	3.513723
GRTH_PCGDP	2.049996	2.094884	2.612700	0.749775
OER	1.958598	1.932736	2.153939	1.565112
REALGDP	29.11463	29.11728	30.31442	27.65803
TARIFF	2.128490	1.945678	3.502802	0.000000
CPI	89.56379	86.50932	128.1094	40.44026

4.2. Descriptive analysis of import demand function

This section analyses the descriptive statistics of the import demand function. To obtain a better picture of how the ICT development index affects imports of goods and services, this study first evaluated the nature of the data. The descriptive statistics for the import demand function (IDF) can be evaluated and analyzed using Table 10. Owing to the large values of our variables, the data on most of them, excluding the indices, are converted to their logarithmic form.

Table 10 summarizes the mean, median, maximum, and minimum values of the variables. The smaller the mean of the variables included in the analysis, the higher the accuracy of the model.

4.2.1. Covariance matrix for import demand function

A covariance matrix is a key statistical tool used to understand the interrelationships between variables in the context of import demand. Table 11 shows how various economic factors are interrelated with import demand.

4.2.2. Unit test root for import demand function

To determine whether the variables in the model are stationary, Levin, Lin and Chu t, lm, Pesaran and Shin W stat, Augmented Dickey Fuller (ADF) – Fisher Chi Square, PP – Fisher Chi Square, and Hadri Z-stat unit root tests were conducted (see Table 12).

DECISION RULE: If the probability values of three out of the five tests are statistically significant at 1%, 5%, or 10%, the variables are stationary; otherwise, they are not stationary.

The unit root results in Table 12 show that the variables used in this study were stationary in order I(0).

4.2.3. Long run relationship test for import demand function

The cointegration test was carried out to examine and evaluate the relationships among the variables in the long run using the Kao cointegration test (see Table 13).

DECISION RULE: We do not accept the null hypothesis in absolute terms if the likelihood ratio of the variable is greater than a critical value.

4.2.4. Short run relationship test for import demand function

To determine the relationship between the explanatory variables in the short run, a Wald test was conducted, the results of which are summarized in Table 14.

Table 11. Covariance matrix of import demand function.

	IMPORT	IDI	GCF_PCGDP	GRTH_PCGDP	OER	REALGDP	TARIFF	CPI
IMPORT	3.292112	1.894675	0.035595	−0.1479	−0.98282	1.518444	−0.71302	19.95872
IDI	1.894675	5.657746	−0.1047	−0.00472	−1.5688	0.51231	−1.22984	42.02764
GCF_PCGDP	0.035595	−0.1047	0.065926	0.027651	0.108686	0.048721	0.047053	−0.38746
GRTH_PCGDP	−0.1479	−0.00472	0.027651	0.350042	−0.00637	−0.15811	0.022442	−2.73093
OER	−0.98282	−1.5688	0.108686	−0.00637	3.886528	−0.47127	0.72807	−3.89029
REALGDP	1.518444	0.51231	0.048721	−0.15811	−0.47127	1.979322	−0.23974	9.118399
TARIFF	−0.71302	−1.22984	0.047053	0.022442	0.72807	−0.23974	0.757317	−11.6064
CPI	19.95872	42.02764	−0.38746	−2.73093	−3.89029	9.118399	−11.6064	688.129

Table 12. Unit root test-summary statistics for import demand function.

Variable	Levin, Lin & Chu t	Im, Pesaran & Shin W-stat	ADF – Fisher Chi Square	PP – Fisher Chi Square	Hadri-Z-stat	Status
Null Hypothesis: Panels contain unit roots						
Imports	1.53092	−2.21511**	47.0160***	46.7419***	10.9054***	I(0)
IDI	−8.81536***	−5.90941***	89.2565***	235.539***	13.2696***	I(0)
GCF_PCGDP	−2.19836**	−1.87478**	35.5465	38.3160*	6.79773***	I(0)
GRTH_PCGDP	6.69622	−3.11520***	61.0185***	91.5075***	1.84878***	I(0)
OER	−2.69704***	−1.36073*	32.1623	30.2108	8.65133***	I(0)
REALGDP	−6.73293***	−2.02512**	40.5554**	34.7429	13.4855***	I(0)
TARIFF	−4.76341***	−2.42931***	46.5232***	47.8961***	11.1823***	I(0)
CPI	−1.38139*	2.83470	40.9704**	35.9514*	12.9851***	I(0)

Note: (*) and (**) show a 5% significance level; (***) indicates significance at the 10%, 5%, and 1% levels, respectively.
Source: Authors' own computations.

Table 13. Kao cointegration test for import demand function.

	Statistic	*p* value
Modified Dickey-Fuller t	−3.0775	0.0010***
Dickey-Fuller t	−3.5377	0.0002***
Augmented Dickey-Fuller t	−1.5676	0.0585*

Note: (*) and (**) show a 5% significance level; (***) indicates significance at the 10%, 5%, and 1% levels, respectively.
Source: Authors' own computations.

4.3. Empirical results

4.3.1. Empirical results of export demand function

To investigate the impact of various determinants on exports in the given scenario, an Ordinary Least Squares (OLS) model is used (see Table 15). Several significant findings have emerged from this investigation. First, the ICT Development Index (IDI) has a strong positive impact on exports, demonstrating that higher ICT development is associated with improved export performance. Variables such as the Gross Capital Formation to Private Consumption Ratio (GCF_PCGDP) and the Real GDP Growth Rate (GRTH_PCGDP) were shown to have insignificant effects on exports because they were not statistically significant. Surprisingly, the Official Exchange Rate (OER) has a slightly significantly negative connection with exports, indicating that a higher official exchange rate might hinder export activity. Furthermore, the tariff variable appears to be a major driver, as higher tariffs are associated with lower exports. Overall, the model displayed significant explanatory power with an impressive R-squared value of 0.97, indicating that the included independent variables accounted for approximately 97% of the variance in exports. Furthermore, the probability associated with the F-statistic (Prob (F-statistic) = 0.000) confirmed the model's overall significance. These findings imply that encouraging ICT development and removing tariff barriers could be critical strategies for improving export performance in the present scenario. However, additional studies are required to test the robustness of the model and investigate additional elements that may influence trade dynamics.

4.3.2. Empirical results of import demand functions

The regression analysis investigates the relationship between imports (the dependent variable) and several independent variables, including the ICT Development Index (IDI), Gross Capital Formation to Private Consumption Ratio (GCF_PCGDP), Real GDP Growth Rate (GRTH_PCGDP), Official Exchange Rate (OER), Real

Table 14. Short run results (Wald test results) for import demand function.

Variable	F-statistic	*p* value	Conclusion
IDI	15.43702	0.0001***	Significant
GCF_PCGDP	9.420133	0.0023***	Significant
GRTH_PCGDP	1.859915	0.1734	Insignificant
OER	1.911373	0.1676	Insignificant
REALGDP	156.3945	0.0000***	Significant
TARIFF	18.89265	0.0000***	Significant
CPI	0.815488	0.3671	Insignificant

Note: (*) and (**) show a 5% significance level; (***) indicates significance at the 10%, 5%, and 1% levels, respectively.
Source: Authors' own computations.

Table 15. Empirical results of export demand function.

Dependent variable: EXPORTS

Method: Least Squares
Date: 07/21/23 Time: 21:04
Sample: 1 31
Included observations: 31

Variable	Coefficient	Std. Error	t-Statistic	Prob.
IDI	0.542540	0.080317	6.754980	0.0000
GCF_PCGDP	−0.069377	0.906470	−0.076535	0.9396
GRTH_PCGDP	−0.021176	0.165413	−0.128021	0.8992
OER	−1.278344	0.620923	−2.058781	0.0505
REER	−0.013910	0.009721	−1.430971	0.1653
TARIFF	−0.275000	0.105050	−2.617806	0.0151
C	29.13893	4.614528	6.314606	0.0000
R-squared	0.978120	Mean dependent var		27.06398
Adjusted R-squared	0.972650	S.D. dependent var		1.370744
S.E. of regression	0.226690	Akaike info criterion		0.065211
Sum squared resid	1.233318	Schwarz criterion		0.389014
Log likelihood	5.989234	Hannan-Quinn criter.		0.170763
F-statistic	178.8179	Durbin-Watson stat		1.073665
Prob(F-statistic)	0.000000			

GDP (REALGDP), Tariff, and the Consumer Price Index (CPI) (see Table 16). These findings indicate that imports were significantly influenced. Notably, Real GDP (REALGDP) and Gross Capital Formation to Private Consumption Ratio (GCF_PCGDP) have strong positive relationships with imports, implying that economic growth and capital investment influence import levels. Similarly, imports are positively influenced by the Real GDP Growth Rate (GRTH_PCGDP) and the Official Exchange Rate (OER), albeit to a lesser extent. By contrast, the tariff variable has a negative effect, showing that higher tariffs lead to lower imports. However, in this model, the ICT Development Index (IDI), Consumer Price Index (CPI), and the constant term do not show statistically significant relationships with imports. The overall model performance was high, with an R-squared value of 0.99, indicating that the independent variables could explain almost 99% of the variance in imports. The regression model provides useful insights into the fundamental determinants impacting import volumes, providing policymakers and enterprises with crucial information for strategic decision making.

4.4. Diagnostic analysis

4.4.1. White's heteroscedasticity test

Heteroscedasticity refers to a data-generation process in which disturbances derived from underlying populations vary. The distribution of Y values around the estimated regression line can be used to visually assess heteroscedasticity. The estimators generated through simple OLS are said to be unbiased and linear but inefficient in the presence of heteroscedasticity because the error term variance and OLS estimators are variance-biased. Consequently, the confidence interval and hypothesis testing were unreliable because the test statistics did not conform to the t and F distributions. The white heteroscedasticity test was used to determine whether the error term in both models had a constant variance, as shown in Table 17.

The null hypothesis (Ho) states that the model's errors are homoscedastic, which means that their variance is constant across all levels of the independent variables. The alternative hypothesis (Ha) proposes that mistakes may display unrestricted heteroscedasticity, suggesting that the variance in errors is not constant and may vary across different independent variable values.

Table 16. Empirical results of import demand function.

Dependent variable: IMPORT				
Method: Least Squares Date: 07/22/23 Time: 13:15 Sample: 1 31 Included observations: 31				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
IDI	−0.126025	0.107521	−1.172096	0.2532
GCF_PCGDP	0.828724	0.442402	1.873239	0.0738
GRTH_PCGDP	0.218416	0.092012	2.373772	0.0263
OER	0.602126	0.319779	1.882942	0.0724
REALGDP	2.014685	0.365734	5.508605	0.0000
TARIFF	−0.167367	0.056219	−2.977026	0.0067
CPI	−0.007453	0.006145	−1.212825	0.2375
C	−34.77089	10.40457	−3.341887	0.0028
R-squared	0.993906	Mean dependent var		26.92777
Adjusted R-squared	0.992051	S.D. dependent var		1.373603
S.E. of regression	0.122463	Akaike info criterion		−1.144382
Sum squared resid	0.344934	Schwarz criterion		−0.774321
Log likelihood	25.73793	Hannan-Quinn criter.		−1.023752
F-statistic	535.8982	Durbin-Watson stat		1.713830
Prob(F-statistic)	0.000000			

Table 17. White's heteroscedasticity test.

White's Heteroscedasticity Test		
Null Hypothesis: Homoscedasticity		
	Chi Sq	Probability
Export demand function	30.42	0.29
Import demand function	31.00	0.41

Source: Authors' own computations.

For the export demand function, the computed chi-square statistic for this test was 30.42, and the related probability (*p* value) was 0.29. Under the null hypothesis, the chi-square statistic reflects the test statistic that evaluates the difference between anticipated and observed frequencies. A significance level of 0.29 refers to the likelihood of observing the observed results if the null hypothesis is true. The null hypothesis cannot be rejected, because the probability value (0.29) is greater than the standard significance level of 0.05. This means that there are insufficient data to infer that the model has strong heteroscedasticity. In other words, the homoscedasticity condition is not violated, and the errors in the regression model are likely to have a constant variance across all levels of independent variables.

For the import demand function, the computed chi-square statistic in this test was 31.00, and the related probability (*p* value) was 0.41. Under the null hypothesis, the chi-square statistic estimates the difference between anticipated and observed frequencies. A significance level of 0.41 represents the likelihood of observing the observed results if the null hypothesis is true. We do not have sufficient evidence to reject the null hypothesis, with a *p* value of 0.41, which is larger than the standard significance level of 0.05. The results indicate that the model does not display considerable heteroscedasticity and that the homoscedasticity assumption is most likely not broken (see Table 17).

4.4.2. Multicollinearity test

A situation in which one or more independent variables can be expressed as a combination of other independent variables is referred to as multicollinearity. A pairwise correlation matrix was used to evaluate and check for multicollinearity among the dependent and independent variables. A Multicollinearity Test was used to determine whether multicollinearity existed among independent variables in the regression model. When two or more independent variables are highly linked, multicollinearity emerges, making it difficult to evaluate the unique contributions of each predictor to the dependent variable. The Mean Variance Inflation Factor (VIF) was used to calculate the degree of multicollinearity.

In the case of the export demand function, as the Mean VIF is less than 10, we can conclude that there is no multicollinearity in the data. For the import demand function, because the Mean VIF is greater than 10, we can conclude that multicollinearity is present in the data (see Table 18).

Table 18. Multicollinearity test.

	EXPORTS	IDI	GCF_PCGDP	GRTH_PCGDP	OER	REER	TARIFF
EXPORTS	1.000000	0.12663	−0.116969	0.065334	−0.53075	0.12483	−0.12620
IDI	0.126634	1.00000	−0.171433	−0.003353	−0.33455	−0.05815	−0.59413
GCF_PCGDP	−0.116969	−0.17143	1.000000	0.182023	0.21471	−0.03797	0.21058
GRTH_PCGDP	0.065334	−0.00335	0.182023	1.000000	−0.00545	−0.15166	0.04358
OER	−0.530755	−0.33455	0.214715	−0.005459	1.00000	−0.10586	0.42437
REER	0.124839	−0.05815	−0.037971	−0.151664	−0.10586	1.00000	−0.14078
TARIFF	−0.126204	−0.59413	0.210583	0.043588	0.42437	−0.14078	1.00000

	IMPORT	IDI	GCF_PCGDP	GRTH_PCGDP	OER	REALGDP	TARIFF	CPI
IMPORT	1.00000	0.43901	0.076405	−0.137775	−0.2747	0.594844	−0.45157	0.41933
IDI	0.43901	1.00000	−0.171433	−0.003353	−0.33455	0.153092	−0.59413	0.67356
GCF_PCGDP	0.07640	−0.17143	1.000000	0.182023	0.2147	0.134873	0.21058	−0.05752
GRTH PCGDP	−0.13777	−0.00335	0.182023	1.000000	−0.00545	−0.189952	0.04358	−0.17596
OER	−0.27476	−0.33455	0.214715	−0.005459	1.0000	−0.169913	0.42437	−0.07522
REALGDP	0.59484	0.15309	0.134873	−0.189952	−0.16991	1.000000	−0.19581	0.24707
TARIFF	−0.45157	−0.59413	0.210583	0.043588	0.4243	−0.195813	1.00000	−0.50841
CPI	0.419334	0.673563	−0.057526	−0.175960	−0.07522	0.247073	−0.50841	1.000000

Source: Authors' own computations.

Table 19. Autocorrelation test.

	Autocorrelation test	
	Export demand function	Import demand function
Dwstat	1.07	1.71

Source: Authors' own computations.

Table 20. Specification test

	Specification test	
	Export demand function	Import demand function
Ovtest	F = 20.70 Prob > F = 0.0000	F = 16.96 Prob > F = 0.0000

Source: Authors' own computations.

4.4.3. Autocorrelation test

The Autocorrelation Test, also known as the Durbin-Watson test, was used to determine whether autocorrelation existed in the residuals of the regression model. Autocorrelation arises when there is a consistent relationship between the residuals at different periods, indicating that the regression model's premise of observation independence may be broken. The Durbin-Watson test statistic (DWSTAT) was used to determine the existence of autocorrelation.

In the case of the export demand function with a DWSTAT value of 1.07, the test result implies that the model's residuals may have minor positive autocorrelation. However, it is crucial to note that the number is close to the critical value of 2, implying that the evidence for strong autocorrelation is relatively poor. In the case of the import demand function with a DWSTAT score of 1.71, the test result implies that the model's residuals may have a minor positive autocorrelation. However, the DWSTAT value was close to the predicted value of 2, indicating that the evidence for considerable autocorrelation was weak (Table 19).

4.4.4. Specification test

The Ramsey RESET test was used to determine whether the regression model neglected any relevant variables that could potentially improve its fit. The null hypothesis (Ho) indicates that there are no omitted variables in the model, implying that all the relevant explanatory factors have been sufficiently incorporated. The alternative hypothesis implies that adding new variables to a model can improve its performance and predictive ability.

For the export demand function, the computed F-statistic for this test was 20.70, and the related probability (*p* value) was 0.0000. The F-statistic is a test statistic that compares the restricted (current) model with the unconstrained model that includes more variables. The *p* value represents the likelihood of seeing the obtained F-statistic if the null hypothesis is true. For the import demand function, the

estimated F-statistic in this test was 16.96, and the related probability (*p* value) was 0.0000. The F-statistic was used to compare the current (limited) model with the unconstrained model, which included more variables. The *p* value denotes the likelihood of observing the F-statistic if the null hypothesis is true. The result was significant with a *p* value of 0.0000. This provides significant evidence to reject the null hypothesis, signalling that the model has omitted variables and that the current specification may not adequately reflect the intricacies of the predictor-dependent variable connection (see Table 20).

4.5. Discussion

The findings of this study contribute significantly to the existing body of knowledge on the relationship between ICT development and international trade, with a particular focus on Pakistan and its trading partners. This study thoroughly investigated the influence of ICT development on trade dynamics by examining export and import demand functions utilizing a comprehensive dataset covering a period of three decades and encompassing 13 countries.

The empirical evidence indicates a substantial and positive impact of the ICT development index (IDI) on both exports and imports, which aligns with the broader discourse on the role of digital technology in facilitating international trade. This supports the theoretical perspectives discussed in the literature review, where the crucial role of ICT in economic growth and productivity, as highlighted by Jorgenson and Vu (2016) and Saqib et al. (2023), is further substantiated by the tangible benefits it provides in enhancing trade volumes. Additionally, the consistency of these findings across various panel data techniques, with only minor variations in the coefficients, underscores the robustness of the analysis and the central role of ICT in trade enhancements.

The use of DOLS for the export demand function and FMOLS for the import demand function not only supports the methodological choices made in the study, but also validates the claims of Kao and Chiang (2001) and Rukhsana and Shahbaz regarding the superiority of these methods in addressing bias and endogeneity issues. The study's findings, specifically that a 1% increase in ICT development leads to a 0.245% increase in exports and a 0.32% increase in imports, highlight the tangible benefits of ICT investment for countries seeking to enhance their trade profiles.

The results of this study are consistent with the prior research discussed in the introduction and literature review, particularly in highlighting the transformative impact of information and communication technology (ICT) on trade. The positive correlation between ICT development and trade metrics is in line with the broader narrative that ICT is a driving force for economic modernization and sustainability. This finding supports the arguments put forth by Lyu et al. (2023) and Chen et al. (2023), who emphasize the role of ICT in facilitating green trade and promoting sustainable economic practices, in alignment with the Sustainable Development Goals (SDGs). The indisputable proof of the positive effects of ICT on trade presents a powerful argument for policymakers in Pakistan beyond investing in ICT infrastructure and policy frameworks that encourage digital innovation. Leveraging ICT to enhance trade can not only increase a country's economic output but also align with global sustainability initiatives.

It has been suggested that Pakistan pursues strategic partnerships with countries such as Singapore and Malaysia. This recommendation is underpinned by ICT's transformative role in reshaping international trade dynamics. Singapore and Malaysia are distinguished by their sophisticated digital infrastructure, comprehensive ICT policies, and remarkable achievements in harnessing technology across various sectors, making them outstanding models for ICT development. By establishing strategic partnerships, Pakistan can gain access to a wealth of knowledge, expertise, and technological innovation, facilitating the exchange of cutting-edge technologies, best practices in digital governance, and collaborative initiatives in ICT projects. These partnerships are anticipated to stimulate Pakistan's ICT sector, drive innovation, enhance digital literacy, and improve the efficiency of trade operations. Collaboration could also create opportunities for Pakistani businesses to access new markets, participate in regional digital economies, and attract foreign investment in technology-driven sectors. Ultimately, such strategic alliances align with this study's recommendations on leveraging ICT for economic development, offering Pakistan a means to strengthen its trade competitiveness and achieve sustainable economic growth in the digital era.

5. Conclusion and policy recommendation

This study makes significant contributions to understanding the impact of ICT on international trade, particularly through a nuanced examination of imports and exports. By examining these critical components of trade, this study enriches the literature by providing detailed insights into how ICT development affects trade dynamics. The implications of these findings are numerous and offer valuable guidance to policymakers and government officials. By integrating ICT development into trade-related policy frameworks, nations can revolutionize their economic landscapes by leveraging digital advancements to foster growth and sustainability. The challenge of accessing comprehensive ICT index data due to subscription barriers and sole reliance on official exchange rates without delving into diverse exchange rate regimes highlights areas where future research could build upon. These limitations emphasize the necessity for a more expansive data collection approach and a broader analytical perspective in subsequent studies.

Pakistan and its trading partners urgently need to join forces to enhance ICT infrastructure and innovation. This entails substantial investments in the ICT sector, the creation of a supportive environment for technological advancement, and a strong emphasis on R&D to spearhead innovative solutions. Moreover, fostering collaboration across various sectors, such as customs, transportation, finance, and insurance, is crucial to fully harnessing ICT's potential of ICT in international trade. Additionally, forging strategic partnerships with technologically advanced countries could serve as catalysts for Pakistan's ICT sector growth, positioning it as a key player in the global digital economy.

Authors' contributions

Conceptualization, M.F., M.A.A., and W. A. W.; methodology, M. F. W. A. W.; validation, M.A. and F.A.R.; formal analysis, A.L.A. and F.A.R; investigation, M.A.A. and A.L.A.; writing—original draft preparation, M.F., M.A.A., and W.A.W; writing—review and editing, M.A. and F.A.R.; funding acquisition, A.L.A. All the authors have read and agreed to the published version of the manuscript.

Disclosure statement

The authors declare no conflict of interest.

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Data availability statement

Supportive data will be provided upon request by the corresponding authors.

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Appendix A.

At first difference:

Variable	Levin, Lin & Chu t	Im, Pesaran and Shin W-stat	ADF – Fisher Chi Square	PP – Fisher Chi Square	Hadri-Z-stat
Exports	60.8990	−8.82075***	126.289***	162.860***	2.20075**
GCF_PCGDP	−6.23891***	−9.06520***	129.599***	236.925***	−1.15509
GRTH_PCGDP	2.41055	−8.83222***	138.791***	242.062***	1.92023**
IDI	1.91437	−8.48256***	121.771***	343.228***	10.6241***
OER	−9.16466***	−9.33075***	124.016***	161.899***	−0.44389
REER	−7.85213***	−1.97119**	40.2748**	31.5420	−0.15662
TARIFF	−10.1231***	−14.0945***	203.548***	391.909***	3.22301***

At second difference:

Variable	Levin, Lin & Chu t	Im, Pesaran and Shin W-stat	ADF – Fisher Chi Square	PP – Fisher Chi Square	Hadri-Z-stat
Exports	52.5922	−19.8154***	301.319***	376.902***	3.46906***
GCF_PCGDP	−12.4962***	−17.5736***	264.968***	306.275***	−0.68600
GRTH_PCGDP	−6.32566***	−15.7977***	236.140***	243.959***	1.46200*
IDI	−7.93038***	−19.6924***	299.199***	313.822***	2.22645**
OER	−16.4243***	−17.4048***	254.598***	274.086***	7.37328***
REER	−16.0507***	−18.2825***	277.181***	333.534***	−1.50643
TARIFF	−12.6383***	−20.5667***	296.217***	221.048***	1.62236

At first difference:

Variable	Levin, Lin & Chu t	Im, Pesaran and Shin W-stat	ADF – Fisher Chi Square	PP – Fisher Chi Square	Hadri-Z-stat
Imports	−250.883***	−79.4023***	171.560***	170.380***	4.86202***
GCF_PCGDP	−13.7414***	−14.4815***	214.489***	236.925***	−1.15509
GRTH_PCGDP	−11.7476***	−15.3181***	229.255***	242.062***	1.92023**
IDI	−24.0695***	−25.1457***	339.906***	343.228***	10.6241***
OER	−13.3032***	−12.0571***	161.974***	161.899***	−0.44389
CPI	−5.33001***	6.64239***	101.539***	106.259***	5.66368***
REALGDP	−0.81305	−5.42897***	83.4083***	89.0165***	4.22672***
TARIFF	−23.6899***	−23.7356***	337.049***	391.909***	3.22301***

At second difference:

Variable	Levin, Lin & Chu t	Im, Pesaran and Shin W-stat	ADF – Fisher Chi Square	PP – Fisher Chi Square	Hadri-Z-stat
Imports	−291.443***	−105.032***	338.592***	345.665***	4.23756***
GCF_PCGDP	−27.5223***	−27.3669***	384.570***	306.275***	−0.68600
GRTH_PCGDP	−24.5557***	−25.1214***	338.333***	243.959***	1.46200*
IDI	−27.4331***	−30.3545***	410.279***	313.822***	2.22645**
OER	−25.2332***	−23.2099***	326.075***	274.086***	7.37328***
CPI	−19.9276***	−18.4528***	267.843***	321.540***	−0.98452
REALGDP	−13.5476***	−16.4226***	243.316***	279.050***	1.85900**
TARIFF	−32.6677***	−33.6984***	410.950***	221.048***	1.62236*

Appendix B.

Author (s), time period, countries	Variables and source	Objective/methodology	Major findings
Abelinsky & Hilbert Time period: 1995–2008 Countries: 122	Variables: Telecommunication quantity, quality, mobile telephony, internet services, bilateral trade, regional trade agreements, GDP, population, currency, language, distance, colony, legal origin, border, world bank governance, paved roads. Source (s): WDI, CEPII and ITU.	Objective: To investigate whether there is a presence of any differential effect of ICT quantity (subscriptions) and quality (bandwidth) on international trade for both the developing as well and developed countries. Methodology: The BB methodology with the inclusion of time dummies in a fixed effects framework.	Found a significant and positive correlation between ICT quality as well as quantity and exports. The study also concluded that in the developing countries, the quality of data speed is more important as compared to the number of ICT subscriptions.
Kurihara, Y., & Fukushima, A. (2013). Time period: 2005 and 2010 Countries: 58	Variables: bilateral trade volume (export plus import), GDP, distance, number of Internet hosts Sources: Direction of Trade Statistics, World Factbook (CIA), IMF, Auroral Rays (http://chihuahua.s171.xrea.com/).	Objective: to study the relationship between the Internet effect and international trade. Methodology: gravity model	The study shows a strong relationship between networks and international trade.
Ahmad et al. (2011) Time period: 1980 to 2008 Countries: 36	Variables: Bilateral trade flows (exports), Real gross domestic product, Endowment, Distance, Exchange Rate, Border, Locked, Infrastructure Source (s): World Bank, World Development Indicators	Objective: to investigate and examine the effect of ICT Infrastructure on trade in Malaysia Methodology: The gravity model, pooled OLS, Random Effects Model (REM) and Fixed Effects Model (FEM).	The results shows that some of ICT components including mobile subscribers, fixed-line telephone subscribers, personal computers and internet users are significantly and positively related to the value of trade between Malaysia and its trading partners.
Salmani et al. (2013) Time period: 1990 to 2011 Countries: 135 developing countries	Variables: GDP, population, distance, exports and imports, Internet variable Source (s):WDI,	Objective: to examine the effect of internet on the notion of international trade in terms of service in developing countries. Methodology: unbalance panel data approach and modified gravity model	The study concluded that the internet users per hundred people have a positive impact on international trade in terms of services.
Time period: 1998–2007 Countries: 28 African countries	Variables: ICT infrastructure, Institutional quality, Educational Attainment, Trade Source (s): ITU, WDI, African Development indicators, UNCTAD	Objective: to investigate how information and communications technology (ICT) infrastructure impacts on intra-African trade Methodology: PLS-based structural equation analysis	The results concluded that telecom infrastructure had a direct as well as indirect impact on trade while educational attainment indirectly influence intra-African trade

(*Continued*)

Appendix B. Continued.

Author (s), time period, countries	Variables and source	Objective/methodology	Major findings
Bojnec and Fertö (2009) Time period: 1995–2003 Countries: OECD countries.	Variables: GDP growth, population, number of Internet users, real GDP, growth in the number of Internet users, distance, and language. Source (s):WDI, CEPII.	Objective: examine the effect of the internet users on the bilateral trade in OECD countries Methodology: gravity model	The study concluded that internet stimulates manufacturing exports of the OECD countries.
Choi (2010) Time period: 1990–2006 Countries: 151	Variables: Service trade (export and import), GDP, Internet, population, financial depth Source: WDI, IMF	Objective: to investigate the impact of Internet on service trade Methodology: pooled ordinary least squares regression, a fixed-effects model, and a panel GMM	The results of the showed that the increase in Internet users per hundred people increased total service trade (export and import)
Chu and Guo (2019) Time period: 2001 to 2017 Countries: 11	Variables: growth rate of exports (imports) growth rate of total trade, telephone users, mobile phone users, internet users, growth rate of real GDP, population, ratio of fixed capital formation to GDP, ratio of government spending to GDP Source (s):WDI	Objective: to examine the effect of ICT on trade between PRC and ASEAN countries. Methodology Hausman test	The results showed that internet and cellular phones positively impacted the imports as well as the bilateral trade of ASEAN countries from PRC.
Choi & Yi, 2009 Time period: 1995–2007 Countries: 93	Variable: GDP, Internet, investment, Government, inflation. Source: IMF, UNCOMTRADE, UNDESA, UNESCO, UNPAN, WITSA, UIS, ITU	Objective: to how internet effects growth Methodology: pooled OLS, random effects, fixed effects, time fixed effects and panel GMM regressions.	The study found evidence that internet plays a significant and positive role in enhancing economic growth
Clarke and Wallsten (2006) Time period: Mid-late 1990s and early 2000s Countries: 179	Variables: results from regressions of total exports, exports to high-income countries, and exports to low-income countries on Internet use and additional control variables suggested in the literature on trade openness. Source: (ICTs), [ITU]	Objective: investigates the effect of the Internet on export behavior. Methodology: Cross-Sectional Gravity Model, standard gravity model specification	The study concluded that the developing countries tend to export more to countries with high internet penetration.
Clarke (2008) Firm-level data, mostly from small and medium-sized enterprises. 1999, 2002 and 2005	Variables: exports, internet users, internet hosts, entry restrictions for ISPs, population, area, GDP per capita, member of WTO, average tariff, political openness, remoteness. Source: Business Environment and Enterprise Performance Survey (BEEPS)	Objective: to examine whether internet access appears to impact the export performance of low and middle-income economies of Eastern Europe and Central Asia. Methodology: OLS, 2SLS, Cross-Sectional Gravity Model	The study concluded that there is a strong correlation between exporting and the internet access at the enterprise level of low and middle-income economies of Eastern Europe and Central Asia.
Demirkan et al. (2009) Time period: 1962 Countries: 175	Variables: GDP, internet, distance, border, language, colonial rel, colonizer. Source (s): U.N. Commodity Trade Statistics Database	Objective: to determine whether physical and cultural distance matters in how ICT affects bilateral trade flows Methodology: gravitational model	The results showed that greater bilateral trade flows tend to occur between countries which have higher Internet use.
Time period: 1995–1999 Countries: 31	Variables: Internet, financial depth, GDP, population, distance, language, adjacency. Source: WDI	Objectives: To determine whether the Internet has significantly affected international service provision in practice Methodology: Gravity model	The results indicated that development of internet has already begun facilitating increased exports of services to the United States.
Freund and Weinhold Time period: 1998–1999 Counties: 56	Variables: GDP, population, distance, adjacency, language, link, FTA, internet hosts. Source: WDI	Objectives: To determine whether the Internet has significantly affected international service provision in practice Methodology: Gravity model	Internet creates a global exchange for goods, thereby reducing market-specific sunk costs of exporting.
Kneller and Timmis (2016) Time period: 1998 and 2008, Countries: 100	Variables: fixed broadband, proportion of exporting firms, exports, sales, age, employment etc. Source: International Trade in Services Inquiry (ITIS)	Objectives: to find the impact of broadband use on the firm-extensive margin of UK service exports. Methodology: ADSL	The study found that there is a significant and positive effect of broadband use on the extensive margin of UK service exports.

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Appendix B. Continued.

Author (s), time period, countries	Variables and source	Objective/methodology	Major findings
Lin (2015) Time period: early 1990s to the year 2006 Countries: 200	Variables: log of trade (export) flow, gross domestic product (GDP) per capita and population, distance, language, border, Internet users per 100 people and dummies for various variables. Source: WDI	Objective: to investigate the impact of Internet use on the value of bilateral exports. Methodology: two-step system GMM method	The study concluded that the internet has a significant and positive effect on bilateral trade flow.
Liu and Nath (2013) Time period: 1995 to 2010 Countries: 40	Variables: growth of telecom investment, international Internet bandwidth, Internet subscriptions and hosts per 100 people, share of total exports/imports in GDP, per capita GDP, and pop growth Source (s): WDI, GDF, ITU	Objective: To examine and investigate whether ICT effects exports and imports in emerging markets Methodology: panel least square (PLS) method	The results showed that Internet subscriptions and hosts have a significant and positive impact on export and imports shares in emerging markets.
Time period: 1999 Countries: 62	Variables: value of exports, income, population, distance, language, transport infrastructure, technology, and knowledge Source (s): Statistics Canada, WDI, CIA, UNDP	Objective: to examine the impact of technology on trade for different levels of development in countries. Methodology: Gravity model	The study concluded that technology can be considered as a barrier to trade for those countries which have lower endowment levels.
Mattes et al. (2012) Time period: 1995–2007 Countries: 29	Variables: Exports, distance, border, language, GDP, transport, ICT development index. Source (s): IMF Dots, WDI, CEPII, ITU.	Objective: to assess the impact of ICT on the notion of international trade Methodology: Gravity model	ICT does have a significant and positive impact on EU trade.
Meijers (2014) Time period: 1990 until 2008 Countries: 162	Variables: per capita GDP log, Growth rate of per capita GDP, openness ratio Trade, Per capita internet use, Inflation, GCF, General government final consumption expenditure, Secondary School Enrollment, population, Land area, Number of telephone lines and Mobile cellular subscribers per 100 people Source (s):ITU, WDI	Objective: to examine the relationship between trade, internet use and economic growth. Methodology: simultaneous equation estimation to address the endogeneity issue	The study concluded that there is a positive and significant role of internet use to openness.
Michael (2011). Time period: 2003–2007. Countries: 162	Variables: Imports and exports of services, GDP per capita, Exchange rate, distance, labor force, number of internet users. Source (s): United Nations Services Trade Database, UN, WDI, World bank	Objective: to identify the major determinants of service trade in Africa Methodology: Gravity model	The results showed that service trade in Africa is significantly and positively influenced by its GDP per capita, labor force, internet facility, colonial history and common language as compared to other variables.
Nath and Liu (2017) Time period: 1995 to 2010 Countries: 40	Variables: Telecom investment growth, Internet Bandwidth, Internet subscriptions, Internet hosts, Per capita GDP growth, Population growth Source (s):WDI, GDF,	Objective: to examine the effects of ICT on international trade in the emerging markets Methodology: fixed effects panel data model	The study found that internet subscriptions and hosts tend to have a significant and positive effect on both exports and imports in the emerging markets.
Ozcan (2018) Time period: 2000–2014 Countries: 35	Variables: GDP, population, durance, ICT, border, language, colony, RTA, landlocked, island. Source (s): DOTS, IMF, WDI, CEPII, ITU, WTO.	Objective: to analyze the impacts ICT on trade between Turkey and its trading partners Methodology: augmented version of the gravity model	The study concluded that ICT is said to have a positive and significant impact on both Turkish trade to its trading partners.
Time period: 2000–2014 Countries: 120	Variables: Bilateral exports, Internet users, GDP, Bilateral distance, colony, border, language. Source (s):CEPII, UN Comtrade, World Bank.	Objective: to examine the impact of internet use on the aggregate trade flow. Methodology: structural gravity model using up to date PPML estimation technique	The results showed that internet use increased trade in countries where the level of ICT is same
Time period: 2004–2013 Countries: 55	Variables: bilateral exports, Internet users, Mobile phone subscriptions, Broadband subscriptions, GDP, Bilateral distance Source (s): IMF, WDI, ITU, World bank, CEPII.	Objective: to examine the impact of Internet, mobile phone, and broadband usage on bilateral flows for high-income, low- and middle-income economies Methodology: dynamic gravity model and panel data	The results showed that the effects of ICT use are sig. for trade flows between high-income countries and from high-income to low- and middle-income countries

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Appendix B. Continued.

Author (s), time period, countries	Variables and source	Objective/methodology	Major findings
Soeng (2020) Time period: 1996 to 2017 Countries: 84 trading partners of Cambodia	Variables: ICT per-capita income, population, foreign direct investment, exchange rate, trade freedom, Generalized System of Preference, border Source (s): IMF, UN, WDI, Heritage Foundation, Cambodia's Ministry of Commerce, UNCTAD	Objective: to investigate the impact of ICT on the goods export performance in Cambodia. Methodology: Hausman-Taylor method	Results concluded that there is an impact and role of ICT in promoting the goods exports of Cambodia.
Tang (2006) Time period: 1960 to 2000 Country: US	Variables: GDP, GDP per capita, IT, tariff, distance, language, NAFTA, English, Imports Source: ITU	Objective: to determines how different forms of telecommunications affects the imports of differentiated goods in USA Methodology: fixed-effect model approach	Adoptions of fixed line telephones, mobile phones, and internet connection in the exporting countries have significant impact on US imports of differentiated goods
Timmis (2012) Time period: 1990–2010 Countries: 38 OECD countries	Variables: Internet Users, Broadband Connections, Any Fixed Line Connection, % Broadband Connections Mobile Phones, Computers, Telephone Lines, Bilateral aggregate export, GDP, distance, border, language, colony regional trade agreements, currency unions, Source (s):ITU, COMTRADE, CEPII	Objective: to investigate the relationship between the Internet technologies and trade in goods Methodology: gravity framework	The study found that due to an increase in adoption within country pairs, there was little significant effect on trade
Vemuri and Siddiqi (2009) Time period: 1985–2005 Countries: 62	Variables: Per capita GDP, distance, Contiguity, common language, colonial links, ICT, internet availability Source (s): IMF, ITU, CEPII, UN database.	Objective: to examine the effect of ICT and internet commercialization on the volume and intensity of international trade Methodology: Hausman-Taylor instrumental variable approach	The study found a positive and significant impact of ICT infrastructure and the availability of Internet on intl trade.
Time period: 2001 Countries: 93	Variables: Exports, Internet Users/ Hosts, Entry Restrictions for ISPs, Monopoly for Data Lines/ ISPs/Leased Lines, Population, Area, GDP per Capita, Oil Exporter, Political Openness, Remoteness. Source (s):COMTRADE, ITU, WDI, WTO	Objective: to examine whether the use of internet affects the export behavior Methodology: OLS, 2SLS.	The study concluded that internet access stimulated exports from poor countries to rich countries
Wheatley and Roe (2005) Time period: 1995–2003 Countries: 79	Variables: trade, GDP, population, distance, language, free trade association, internet penetration. Source (s): Foreign Agricultural Trade of the United States database of the Foreign Agricultural Service of the United States Department of Agriculture, Internet Software Corporation's (ISC) survey, WDI, WTO, CIA	Objective: to examine the impacts of the internet on agricultural trade. Methodology: gravity model	The study concluded that internet augmented imports of various commodities to the United States
Xing (2018) Countries: 21 developing- and least-developed countries and 30 OECD countries.	Variables: trade, distance, language, colony, telephone, cellphone, broadband, internet security, internet user, shipping cost, GDP per capita Source (s):WDI, CEPII, OECD, INSEAD, WEF	Objective: to investigate the effect of Internet & e-commerce adoption on bilateral trade Methodology: augmented gravity model with fixed effects	The results showed that better access to the ICT and e-commerce adaption stimulated bilateral trade flows at various levels