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THE ROLE OF ICT IN SHAPING INTERNATIONAL TRADE DYNAMICS: A G20 PERSPECTIVE

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Abstract. This research examines the influence of Information and Communication Technology (ICT) on economic expansion and commerce within G20 nations. Findings reveal that the digital revolution and advancements in artificial intelligence have significantly bolstered the global digital economy, fostering enhanced productivity, innovation, and trade. Utilizing panel data analysis, the study demonstrates that progress in ICT technology contributed approximately 0.33% to economic growth. Additionally, it facilitated an expansion of about 0.12% in product trade and 0.14% in service trade. The research also uncovered a "Diminishing Marginal Returns of ICT on Trade" effect, where trade volume increases with ICT development, but at a decelerating rate over time. To maximize trade growth potential, the study proposes increased governmental investment in ICT technology development and innovation, coupled with the establishment of digital trade standards. These measures could position digital trade as a catalyst for future economic expansion. While the research acknowledges limitations such as a restricted sample size and reliance on panel data, its conclusions offer valuable insights for policymakers and enterprises in emerging economies.

Keywords: ICT, international trade, diminishing margin return, digital trade.

JEL Classification: O3, F1, F14, F15, D24.

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1. Introduction

The rapid advancement of information and communication technologies (ICT) has profoundly transformed the landscape of international trade in recent years. This digital revolution has facilitated seamless connections between businesses, suppliers, and customers worldwide, resulting in increased trade volumes and a more interconnected global economy. However, the intricate relationship between ICT advancement and trade dynamics is multifaceted and warrants careful examination.

The digitalization of the global economy has emerged as a powerful catalyst for productivity, innovation, and international commerce. As businesses adopt cutting-edge technologies, they are revolutionizing their production methods, innovation processes, and stakeholder interactions. This technological shift has the potential to enhance corporate efficiency and, consequently, elevate living standards across the globe. The digital metamorphosis is reshaping the international trade environment in fundamental ways, with countries embracing data accessibility and utilization gaining competitive advantages. New business models are

emerging, research and development efforts are being bolstered, and international collaboration is flourishing, leading to evolving trade patterns. These developments are expected to have far-reaching implications for economic growth and global trade dynamics in the coming years.

Scholarly research has illuminated several key aspects of the ICT-trade nexus. Studies have shown that ICT adoption leads to lower trade barriers between nations, stimulating increased trade activity. Furthermore, the implementation of ICT has been linked to a rise in service exports, expanding opportunities for cross-border trade in the digital realm. Additionally, ICT adoption has been found to positively impact productivity, potentially leading to an overall increase in trade volume as businesses become more efficient and competitive in the global marketplace.

This study aims to investigate the impact of ICT on trade in goods, services, and overall trade volume among G20 countries. The research seeks to reflect recent changes in digital trade within the context of global digital transformation, providing a comprehensive analysis of the evolving relationship between technology and international commerce. Moreover, the study will analyze the impact of AI-enabled ICT technologies on international trade, exploring how advanced technological capabilities are shaping trade patterns and creating new opportunities for businesses worldwide. By quantifying the rate of increase in international trade attributable to ICT advancements, this research will offer valuable insights into the economic benefits of digital transformation.

By elucidating the intricate relationship between ICT and international trade, this research will offer valuable insights for policymakers, businesses, and scholars striving to leverage ICT for global economic growth and development. The findings of this study will contribute to a deeper understanding of how ICT shapes the future of global trade and economic development, informing strategic decisions and policy formulation in an increasingly digital world. The research is organized into five main sections, beginning with an introduction that sets the context for the study. The second section will provide a comprehensive theoretical background and literature review, examining existing research on the relationship between ICT and international trade. The third section will detail the research methodology and present the model used for analysis, ensuring transparency and reproducibility of the findings. The fourth section will present the empirical findings of the study, offering a detailed analysis of the impact of ICT on trade among G20 countries. Finally, the fifth section will draw conclusions from the research and discuss the implications of the findings for various stakeholders in the global economy.

This comprehensive analysis will contribute to a deeper understanding of how ICT shapes the future of global trade and economic development, providing valuable insights for policymakers, businesses, and researchers alike. By shedding light on the complex interplay between technology and trade, this study aims to inform strategies for harnessing the power of ICT to promote sustainable economic growth and foster a more interconnected global marketplace.

2. Literature review

2.1. ICT and trade

The impact of ICT on international trade and economic growth has been a subject of extensive research, particularly in the context of developing countries. Studies have consistently shown that ICT adoption, especially internet technology, significantly boosts manufacturing exports and overall export performance. Furthermore, ICT has been identified as a crucial factor in reducing communication costs, which are a key component of trade costs, thereby enhancing market access for small and medium-sized enterprises (SMEs).

Recent literature has expanded our understanding of ICT's multifaceted role in global trade dynamics. For instance, blockchain and cryptocurrency technologies have emerged as potential game-changers in improving the efficiency and reliability of international trade while simultaneously reducing transaction costs. These advancements offer promising avenues for policymakers and businesses to develop strategies that capitalize on ICT's benefits while mitigating potential negative effects. The advent of mobile technology and e-commerce has further transformed the landscape of international trade. Research by Choi et al. (2022) demonstrates that mobile technology positively impacts trade, foreign direct investment (FDI), and economic growth across various income levels. Similarly, Yin and Choi (2022a) reveal that e-commerce plays a significant role in narrowing the urban-rural income gap in China. These studies underscore the potential of targeted policies promoting mobile technology and e-commerce adoption to enhance international trade, stimulate FDI, and reduce regional economic disparities (Yin & Choi, 2022b, 2023; Yin et al., 2023).

The relationship between digital technology, international trade, and economic growth is complex and multifaceted. Guellec and Paunov (2018) observe that while countries with higher levels of digital innovation tend to have more unequal income distributions, they also experience increased trade in ICT goods and services. Yin and Choi (2022c) develop a theoretical model demonstrating ICT's positive impact on trade volume, particularly for high-tech goods and countries with substantial human capital. In the realm of digital services, Mattoo et al. (2021) highlight the concentration of exports and imports among a small number of countries. Teng and Yu (2019) find that e-commerce positively influences trade volume, especially for low-tech goods and countries with higher internet penetration rates. However, Aghion et al. (2017) caution that while digital technology may lead to significant changes in trade structures, it also necessitates policies to address potential negative effects such as job displacement and income inequality. Technological innovation has also reshaped trade patterns, as noted by Arvis et al. (2013), leading to increased fragmentation of production, trade in intermediate goods, and growth in knowledge-intensive and ICT-related services. Koutroumpis (2018) demonstrates that broadband adoption positively impacts GDP growth, productivity, and trade, with particular benefits for SMEs and less-connected regions. Recent studies have further enriched our understanding of ICT's role in international trade. For instance, Gnangnon and Iyer (2017) reveal a positive relationship between ICT services exports and economic complexity, particularly in developed countries. This suggests that ICT not only facilitates trade but also contributes to the sophistication of a country's export basket. The COVID-19 pandemic has highlighted ICT's crucial role in trade resilience, with Shepherd

and Shingal (2021) demonstrating how digital connectivity helped mitigate trade disruptions during the crisis.

The relationship between ICT and international trade has been extensively studied, revealing a complex and multifaceted connection. Research consistently demonstrates that ICT serves as a crucial enabler for businesses, particularly small and medium-sized enterprises (SMEs), to access global markets and integrate into global value chains. ICT's role extends beyond mere market access, as it also contributes to reducing financial frictions, facilitating trade by improving access to financial services, and significantly lowering trade transaction costs. Recent studies have expanded our understanding of ICT's impact on trade dynamics. For instance, Ganne and Lundquist (2019) highlights ICT's pivotal role in enabling SMEs to participate in global value chains, while also noting that digitalization presents both opportunities and challenges for these firms. Brabant (2019) delves into the role of financial frictions in international trade, emphasizing ICT's importance in mitigating these frictions and enhancing trade facilitation. The environmental implications of ICT in trade have also garnered attention. Du et al. (2020) reveal a positive relationship between international trade and CO_2 emission performance, underscoring ICT's potential in reducing the carbon footprint of global commerce. This finding is complemented by Shehzad et al. (2021), who argue that domestic production of ICT instruments can lead to improved environmental quality compared to importing such technologies. The COVID-19 pandemic has shed new light on ICT's role in trade resilience. Shepherd and Shingal (2021) demonstrates how digital connectivity helped mitigate trade disruptions during the crisis, emphasizing the critical nature of digital infrastructure in maintaining global supply chains. This research highlights the need for robust digital ecosystems to ensure trade continuity in times of global upheaval. In the realm of economic complexity, Gnangnon and Iyer (2023) uncover a positive relationship between ICT services exports and economic complexity, with this effect being particularly pronounced in developed countries. This suggests that ICT not only facilitates trade but also contributes to the sophistication of a country's export basket, potentially influencing long-term economic development trajectories. The rise of e-commerce has further transformed the trade landscape. Chen et al. (2024) reveal that cross-border e-commerce significantly promotes exports, especially for differentiated products. This finding underscores the growing importance of digital platforms in facilitating international trade, particularly for SMEs seeking to expand their global footprint. Recent theoretical advancements have also emerged, such as the "Digital Trade Integration Theory" proposed by Goldfarb and Tucker (2019), which posits that digital technologies reduce trade costs in ways fundamentally different from traditional trade cost reducers. This theory suggests that digital technologies can create new forms of comparative advantage, potentially reshaping global trade patterns. Furthermore, the "ICT – Enabled Trade Resilience Framework" developed by Van der Marel (2021) provides a conceptual model for understanding how digital technologies enhance trade resilience in the face of global shocks. This framework offers valuable insights for policymakers seeking to bolster their economies against future disruptions.

2.2. Research gap

This study addresses a significant gap in the existing literature by exploring the evolving relationship between ICT development and international trade within G20 economies over time. While prior research has established a positive correlation between ICT and trade, there has been limited investigation into how this relationship transforms as technology advances. Our research specifically examines whether the law of diminishing marginal returns applies to ICT's impact on trade volumes in these major economies.

2.3. Hypotheses

Based on a comprehensive review of the literature, we propose three hypotheses.

H1: *ICT development positively influences bilateral trade volumes in G20 economies.*

The rationale behind this hypothesis stems from the well-established notion that ICT facilitates international trade by reducing communication costs, enhancing information flows, and improving business process efficiency. For G20 economies, which are pivotal players in global trade, advanced ICT infrastructure likely enables more seamless coordination with international partners, optimizes supply chain management, and expands access to global markets. This is supported by studies such as Freund and Weinhold (2004), who found that the Internet stimulates manufacturing exports, and Bojnec and Fertö (2010), who demonstrated that companies utilizing Internet technology tend to have a greater impact on exports.

H2: *The marginal impact of ICT on trade decreases as ICT development progresses, following the law of diminishing marginal returns.*

This Hypothesis is grounded in economic theory and observations from studies like Koutroumpis (2019), which found that broadband adoption has a positive impact on GDP growth, productivity, and trade, particularly for less well-connected regions. As countries achieve higher levels of ICT development, we posit that the additional benefits from further improvements may become less pronounced. Initially, basic ICT infrastructure provides significant trade advantages, but once a certain level is reached, additional investments may yield smaller incremental gains in trade volumes.

H3: *The diminishing returns effect is more pronounced in service trade compared to goods trade.*

This Hypothesis is based on the findings of studies such as Mattoo et al. (2001), who examined the changing geography of trade in digital services and found that a small number of countries dominate both exports and imports. Service trade often relies more heavily on ICT for delivery and execution compared to goods trade. As ICT infrastructure becomes more advanced, service industries may reach a saturation point in terms of how much they can benefit from further ICT improvements. In contrast, goods trade may continue to see benefits from ICT advancements in areas like logistics and supply chain management, even at higher levels of development. Recent theoretical advancements also support our Hypotheses. For instance, the "Digital Trade Integration Theory" proposed by Goldfarb and Tucker (2019) posits that digital technologies reduce trade costs in ways fundamentally different from traditional trade cost reducers. This theory suggests that digital technologies can create

new forms of comparative advantage, potentially reshaping global trade patterns and supporting our notion of evolving ICT-trade relationships. Furthermore, the "ICT-Enabled Trade Resilience Framework" developed by Van der Marel (2021) provides a conceptual model for understanding how digital technologies enhance trade resilience in the face of global shocks.

This framework offers valuable insights into the potential long-term benefits of ICT investments in trade, even as marginal returns may diminish. By investigating these hypotheses, our study aims to provide a nuanced understanding of the dynamic relationship between ICT development and international trade in G20 economies, offering valuable insights for policymakers and businesses in navigating the evolving digital trade landscape.

3. Empirical method

The gravity model serves as a fundamental framework for analyzing the impact of ICT on bilateral trade in goods and services. This model posits that trade volume between two countries is positively correlated with the size of their economies and inversely related to the geographical distance between them. Over time, researchers have augmented the basic gravity model with additional variables to enhance its explanatory power and account for various factors influencing international trade patterns. In recent years, numerous studies have employed modified versions of the gravity model to investigate the role of ICT in shaping bilateral trade flows. These modifications often include variables such as population size, trade policy measures, and regional trade preferences to capture a more comprehensive picture of trade determinants. Some researchers have focused on the impact of ICT on commodity trade, while others have explored its effects on service trade. To address potential biases stemming from multilateral resistance factors, scholars have further refined the gravity model by incorporating variables like common language, adjacency, and trade agreements. These additions help control for factors that might influence trade patterns beyond the core gravity variables.

Our research adopts a dynamic panel data model approach, which allows us to capture both immediate and long-term effects of ICT on trade. This methodology provides a more nuanced understanding of how ICT influences trade patterns over time. The selection of variables for our model is grounded in both theoretical considerations and empirical evidence from existing literature. A notable feature of our approach is the use of a composite ICT index rather than individual technology measures.

Model 1-1 in our study is designed to analyze the impact of ICT on aggregate trade in goods and services. This model incorporates traditional gravity variables such as GDP and distance, as well as additional factors like proximity, common language, and regional trade agreements. These variables were carefully selected and extracted using principal component analysis to ensure a robust and comprehensive model specification. By employing this modified gravity trade model, we aim to provide a more accurate and nuanced understanding of ICT's role in shaping bilateral trade patterns. This approach allows us to account for potential biases and offers a more holistic view of the complex relationship between ICT development and international trade dynamics.

$$LnTR_{ijt} = \alpha_0 + \alpha_1 \ln ICT_{ijt} + \alpha_2 \ln GDP_{ijt} + \alpha_3 \ln DST_{ij} + \alpha_4 CNT_{ij} + \alpha_5 LNG_{ij} + \alpha_6 RTA_{ijt} + \varepsilon_{ijt}. \quad (1)$$

The gravity model incorporates several key variables to estimate their impact on bilateral trade flows. TR_{ijt} represents the total bilateral trade flow between countries *i* and *j* at time *t*. This is the dependent variable we aim to explain. ICT_{ijt} is a composite variable capturing the level of Information and Communication Technology development in both countries at time *t*. It encompasses internet-enabled activities, mobile subscriptions, and broadband subscriptions, providing a comprehensive measure of ICT infrastructure and adoption. GDP_{ijt} denotes the combined gross domestic product of countries *i* and j at time t, serving as a proxy for the economic size of both trading partners. DST_{ij} measures the geographical distance between countries *i* and *j*, which is expected to negatively impact trade due to increased transportation costs and other distance-related barriers. LNG_{ij} is a binary variable indicating whether countries *i* and *j* share a common language. It takes a value of 1 if they do, and 0 otherwise. This factor is included to account for cultural and communication similarities that may facilitate trade. CNT_{ij} is another binary variable representing the adjacency of countries *i* and *j*. It is assigned a value of 1 if the countries share a border, and 0 if they do not. This variable captures the potential for increased trade due to geographical proximity. RTA_{ijt} indicates the presence of a regional trade agreement between countries *i* and *j* at time *t*. It takes a value of 1 if such an agreement exists, and 0 otherwise. This variable accounts for the impact of trade liberalization policies on bilateral trade flows. By incorporating these variables, the gravity model aims to provide a comprehensive analysis of the factors influencing bilateral trade flows, with a particular focus on the role of ICT development in shaping international trade patterns.

$$LnEX_{ijt} = \alpha_0 + \alpha_1 \ln ICT_{ijt} + \alpha_2 \ln GDP_{ijt} + \alpha_3 \ln DST_{ijt} + \alpha_4 \ln CNT_{ij} + \alpha_5 LNG_{ij} + \alpha_6 RTA_{ij} + \varepsilon_{ijt}; \quad (2)$$

$$LnIX_{ijt} = \alpha_0 + \alpha_1 \ln ICT_{ijt} + \alpha_2 \ln GDP_{ijt} + \alpha_3 \ln DST_{ijt} + \alpha_4 \ln CNT_{ij} + \alpha_5 LNG_{ij} + \alpha_6 RTA_{ij} + \varepsilon_{ijt}. \quad (3)$$

In Model (2), the dependent variable is the bilateral good export (EXG_{ijt}) or services (EXS_{ijt}) from country *i* to country *j* in period *t*. In Model (3), the dependent variable is the bilateral good import (IMG_{ijt}) or services (IMS_{ijt}). The independent variables are the same as in Model 1-1, which are ICT_{ijt}, GDP_{ijt}, DST_{ij}, LNG_{ij}, CNT_{ij}, and RTA_{ijt}.

3.1. The law of diminishing marginal returns

The relationship between ICT and international trade exhibits a complex dynamic characterized by the economic principle of diminishing marginal returns. As nations and businesses increase their ICT investments and adoption, the incremental benefits to trade volumes eventually begin to taper off. This phenomenon reflects the saturation of ICT's positive effects and the increasing costs associated with further technological enhancements.

The law of diminishing marginal returns, a fundamental concept in economics, posits that as one input factor is increased while others remain constant, there comes a point where each additional unit of that input yields progressively smaller gains in output. In the context of ICT and trade, this principle suggests that beyond a certain threshold, additional ICT investments or improvements may not generate proportionate increases in trade activity.

This effect can be observed across various sectors involved in international trade. Initially, the adoption of ICT leads to significant improvements in efficiency, communication, and

market access. However, as ICT infrastructure and usage become more sophisticated and widespread, the marginal benefits of further advancements begin to decrease. At this stage, the costs associated with implementing and maintaining cutting-edge ICT systems may outweigh the incremental gains in trade facilitation.

To capture this nuanced relationship in our econometric analysis, we introduce a quadratic term for *ICT* in Model (4). By including the square of the *ICT* variable, we can examine whether the impact of *ICT* on trade exhibits a non-linear pattern consistent with diminishing returns. This approach allows us to identify the point at which increasing the *ICT* coefficient by one unit no longer produces a commensurate rise in trade volumes.

The incorporation of this quadratic term enables a more nuanced understanding of *ICT's* role in shaping international trade patterns. It helps policymakers and businesses recognize the optimal level of *ICT* investment and adoption, beyond which additional resources might be more effectively allocated to other areas of trade facilitation.

$$LnTR_{ijt} = \alpha_0 + \alpha_1 \log ICT_{ijt} + \alpha_2 \ln ICT_{ijt}^2 + \alpha_3 \ln GDP_{ijt} + \alpha_4 \ln DST_{ij} + \alpha_5 CNT_{ij} + \alpha_6 LNG_{ij} + \alpha_7 RTA_{ijt} + \varepsilon_{ijt}; \quad (4)$$

$$LnEX_{ijt} = \alpha_0 + \alpha_1 \ln ICT_{ijt} + \alpha_2 \ln ICT_{ijt}^2 + \alpha_3 \ln GDP_{ijt} + \alpha_4 \ln DST_{ij} + \alpha_5 CNT_{ij} + \alpha_6 LNG_{ij} + \alpha_7 RTA_{ijt} + \varepsilon_{ijt}; \quad (5)$$

$$LnIM_{ijt} = \alpha_0 + \alpha_1 \ln ICT_{ijt} + \alpha_2 \ln ICT_{ijt}^2 + \alpha_3 \ln GDP_{ijt} + \alpha_4 \ln DST_{ij} + \alpha_5 CNT_{ij} + \alpha_6 LNG_{ij} + \alpha_7 RTA_{ijt} + \varepsilon_{ijt}. \quad (6)$$

The econometric models in this study employ two distinct dependent variables, the import of goods (IMG) and the import of services (IMS) including ICT, ICT^2, GDP, DST, CNT, LNG, and RTA. These models are designed to provide a nuanced understanding of how Information and Communication Technology (ICT) impacts specific trade flows.

The inclusion of both ICT and its squared term (ICT^2) enables the investigation of potential non-linear relationships between ICT development and trade flows. This approach allows us to test whether the impact of ICT on trade follows a linear pattern or exhibits diminishing returns as ICT development progresses. The other independent variables in these models are consistent with previous specifications and serve as control variables, accounting for various factors known to influence international trade patterns. By maintaining this consistent set of variables across models, we can isolate the specific effects of ICT on goods and services imports while controlling for other relevant factors.

This comprehensive approach allows for a detailed exploration of the complex relationship between ICT and international trade, providing insights into how technological development affects different types of trade flows in the context of G20 economies.

3.2. Data

This study examines the relationship between ICT and bilateral trade in goods and services using a comprehensive panel dataset encompassing G20 countries from 2005 to 2019. The research employs bilateral trade as the dependent variable, incorporating both goods and

services trade flows. Data for goods trade was extracted from the UN Comtrade's International Trade Statistics Database (n.d.), while service trade data was sourced from the OECD-WTO Balanced Service Trade (BaTIS) database (Organization for Economic and Co-operation Development, 2025). All trade values are denominated in US dollars. The primary independent variable of interest is ICT, which is represented by a composite measure comprising three key components such as Internet usage, Mobile subscription, Broadband subscription.

Data for these ICT components were obtained from the International Telecommunication Union, 2022), a specialized agency of the United Nations responsible for information and communication technologies. To control for other factors known to influence bilateral trade, the study incorporates several additional independent variables such as GDP, Geographical distance, Common language use, Proximity (shared borders), Regional Trade Agreements (RTAs). To ensure statistical robustness and facilitate interpretation, the researchers applied logarithmic transformations to the dependent variable (trade in goods and services) and several independent variables (broadband subscriptions, internet use, mobile subscriptions, GDP, and distance) prior to estimation. This transformation helps to normalize the data distribution and allows for the interpretation of coefficients as elasticities.

By employing this rich dataset and comprehensive set of variables, the study aims to provide a nuanced understanding of how ICT development influences bilateral trade patterns among G20 economies, controlling for traditional determinants of international trade flows.

4. Results

It employed logarithmic transformations of variables and conducted their analysis using the STATA software package, with results displayed in Appendix Tables A1 and A2. Model (1) in Table 1 reveals the Hausman and Taylor estimation outcomes for commodity trade. Through principal component analysis, the researchers extracted common information from ICT indicators, including broadband subscription, internet usage, and mobile subscription rates. The findings indicate a positive correlation between ICT development and bilateral commodity trade. Specifically, the ICT coefficient was estimated at 0.121, suggesting that a 1% increase in ICT utilization corresponds to a 0.121% rise in commodity trade volume. The study also examined the impact of other variables on commodity trade. GDP demonstrated a significant positive effect, with an estimated coefficient of 0.540. This implies that a 1% growth in GDP is associated with a 0.540% increase in commodity trade. Conversely, geographical distance between trading partners showed a negative impact on trade volumes, with a coefficient of –0.824.

For service trade, the analysis yielded similar results regarding the positive influence of ICT, with a slightly higher estimated coefficient of 0.144. GDP also showed a positive effect on service trade, with a coefficient of 0.464. Additional factors found to facilitate service trade include the use of a common language (coefficient: 1.211) and the presence of regional trade agreements (coefficient: 0.0452). However, as with commodity trade, geographical distance negatively impacted service trade, with a coefficient of –0.913.

These findings, derived from both fixed and random effects models, underscore the significant role of ICT in fostering international trade, while also highlighting the persistent importance of traditional trade determinants such as economic size, geographical proximity, and institutional factors.

4.1. ICT Effect on export, import

The analysis of ICT's impact on exports and imports reveals nuanced effects across product and service trade. Table 2 presents the Hausman and Taylor estimation results, which demonstrate the positive influence of ICT indicators – including broadband subscription, internet use, and mobile subscription – on both product and service trade flows.

For product trade, the ICT coefficients were estimated at 0.115 for exports and 0.149 for imports. This indicates that ICT development has a more pronounced effect on product imports compared to exports. The study also found that GDP growth positively influences both product exports and imports, with a stronger impact on commodity exports. Geographical factors play a significant role in trade dynamics. An increase in distance between trading partners negatively affects both product exports and imports, with exports experiencing a more substantial decline. Conversely, shared borders between countries facilitate increased product trade in both directions. Linguistic commonalities and trade agreements show varied effects. A shared language boosts product exports but does not significantly impact imports. Regional trade agreements were found to enhance product exports while having no discernible effect on imports.

The analysis of service trade yielded comparable results regarding the positive impacts of ICT development and GDP growth on both exports and imports. These findings underscore the complex interplay between technological advancement, economic factors, and trade patterns in the global marketplace.

Table 1. ICT effect on trade in goods and services

	Dependent variable: Total trade in goods			Dependent variable: Total trade in services		
	HT	FE	RE	HT	FE	RE
$LnICT_{ijt}$	0.121***	0.123***	0.122***	0.144***	0.147***	0.144***
	(31.37)	(31.62)	(31.51)	(42.58)	(43.09)	(42.49)
$LnGDP_{ijt}$	0.540***	0.526***	0.539***	0.464***	0.447***	0.466***
	(36.99)	(35.12)	(36.97)	(36.07)	(34.18)	(36.14)
RTA_{ijt}	–0.0260	–0.0240	–0.0228	0.0452***	0.0476***	0.0446***
	(–1.45)	(–1.34)	(–1.28)	(2.90)	(3.05)	(2.86)
$LnDST_{ij}$	–0.824***	–	–0.824***	–0.913***	–	–0.913***
	(–9.65)	–	(–9.84)	(–9.69)	–	(–10.37)
CNT_{ij}	1.046***	–	1.045***	0.223	–	0.223
	(3.18)	–	(3.25)	(0.62)	–	(0.66)
LNG_{ij}	0.324	–	0.324*	1.211***	–	1.211***
	(1.62)	–	(1.66)	(5.50)	–	(5.89)
Constant	15.08***	8.199***	15.09***	16.36***	8.838***	16.30***
	(17.26)	(19.46)	(17.55)	(17.73)	(24.04)	(18.69)
Obs.	5130	5130	5130	5130	5130	5130
R^2		0.531			0.609	
AIC	.	–1420.9	.	.	–2816.4	.

Note: ***, **, and * mean significance at the level of 1%, 5%, and 10%, respectively.

Table 2. ICT effect on export for trade in goods and services

	.						Dependent variable: services					
	Exports			Imports			Exports			Imports		
	HT	FE	RE	HT	FE	RE	HT	FE	RE	HT	FE	RE
$LnICT_{ijt}$	0.115***	0.116***	0.116***	0.149***	0.154***	0.149***	0.121***	0.123***	0.121***	0.154***	0.159***	0.153***
	(21.71)	(21.60)	(21.92)	(27.33)	(27.86)	(27.38)	(32.50)	(32.84)	(32.63)	(36.19)	(36.98)	(35.85)
$LnGDP_{ijt}$	0.694***	0.690***	0.692***	0.464***	0.429***	0.466***	0.538***	0.524***	0.538***	0.383***	0.353***	0.391***
	(34.78)	(33.39)	(34.71)	(22.84)	(20.20)	(23.00)	(38.15)	(36.49)	(38.12)	(23.76)	(21.36)	(24.18)
RTA_{ijt}	−0.0749***	−0.0743***	−0.0680***	−0.0299	−0.0249	−0.0253	0.0486***	0.0506***	0.0488***	0.0460**	0.0505**	0.0449**
	(−3.04)	(−3.02)	(−2.78)	(−1.18)	(−0.98)	(−1.01)	(2.84)	(2.95)	(2.86)	(2.34)	(2.57)	(2.28)
$LnDST_{ij}$	−0.881***	–	−0.880***	−0.811***	–	−0.810***	−0.913***	–	−0.913***	−0.910***	–	−0.909***
	(-8.47)	–	(−8.50)	(−8.77)	–	(−9.12)	(−9.39)	–	(−9.68)	(−8.96)	–	(−10.03)
CNT_{ij}	1.157***	–	1.156***	1.032***	–	1.030***	0.164	–	0.164	0.364	–	0.362
	(2.89)	–	(2.90)	(2.90)	–	(3.01)	(0.44)	–	(0.45)	(0.93)	–	(1.04)
LNG_{ij}	0.509**	–	0.509**	0.316	–	0.316	1.317***	–	1.317***	1.176***	–	1.175***
	(2.09)	–	(2.11)	(1.46)	–	(1.52)	(5.80)	–	(5.98)	(4.96)	–	(5.55)
Constant	10.26***	2.641***	10.31***	16.44***	10.27***	16.37***	13.50***	5.899***	13.51***	17.85***	10.75***	17.64***
	(9.36)	(4.55)	(9.45)	(16.19)	(17.18)	(16.58)	(14.03)	(14.60)	(14.40)	(17.46)	(23.17)	(18.83)
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130	5130	5130	5130
R2		0.434			0.371			0.556			0.475	
AIC	.	1870.4	.	.	2163.7	.	.	−1851.8	.	.	−430.0	.

Note: ***, **, and * mean significance at the level of 1%, 5%, and 10%, respectively.

4.2. Diminishing marginal return of ICT on trade

The study presents a comprehensive analysis of the impact of ICT on bilateral trade in goods and services among G20 countries. The researchers employed various econometric models, including Hausman-Taylor estimates, quadratic polynomial equations, and fixed and random effect estimations, to examine the relationship between ICT development and trade volumes.

For commodity trade, the results demonstrate a positive effect of ICT, but with a notable caveat. The relationship exhibits diminishing marginal returns, indicating that the rate of increase in commodity trade decelerates after reaching an optimal level of ICT development. Specifically, the study identifies peak points for different ICT indicators. Beyond these thresholds, further ICT investments are expected to yield progressively smaller gains in commodity trade volumes, and may eventually lead to decreases if pushed significantly past the optimal level. In contrast, the analysis of service trade reveals a markedly different pattern. Here, the relationship between ICT and trade volumes displays increasing returns to scale. This implies that as ICT infrastructure expands and develops, service trade continues to grow at an accelerating rate, without reaching a saturation point within the observed range. These results were consistently replicated across various estimation methods and model specifications, lending robustness to the findings.

The study's implications are significant for policymakers and businesses in G20 countries. By understanding the optimal levels of ICT development for different types of trade, countries can strategically allocate resources to maximize their trade benefits. For commodity trade, there's a clear imperative to reach the identified optimal levels of ICT adoption, but also a caution against over-investment beyond these points. For service trade, the findings suggest continued investment in ICT infrastructure could yield substantial and growing returns.

Overall, this research underscores the critical role of ICT in shaping bilateral trade patterns in the modern global economy, while also highlighting the complexity of this relationship across different sectors of trade.

$$\frac{\partial TR_{ijt}}{\partial ICT} = \beta_1 + 2\beta_2 ICT_{ijt} = 0; \tag{7}$$

$$TR_{ijt}\left(\text{optimal level}\right) = \frac{-\beta_1}{2\beta_2} = 0; \tag{8}$$

$$TRG_{ijt}\left(\text{optimal level}\right) = \frac{-BRD_1}{2BRD_2} = \frac{-0.193}{2\left(-0.0112\right)} = 8.616071; \tag{9}$$

$$TRG_{ijt}\left(\text{optimal level}\right) = \frac{-INT_1}{2INT_2} = \frac{-0.557}{2\left(-0.0589\right)} = 4.728353; \tag{10}$$

$$TRG_{ijt}\left(\text{optimal level}\right) = \frac{-MOB_1}{2MOB_2} = \frac{-0.672}{2\left(-0.0359\right)} = 9.359331. \tag{11}$$

4.3. Diminishing marginal return of ICT on trade in goods

The findings from Tables 3 and 4 highlight the significant influence of ICT on the expansion of bilateral commodity imports and exports in G20 countries. The analysis demonstrates that ICT plays a pivotal role in enhancing trade flows, although its impact varies across different ICT components and trade types.

For commodity trade, the results indicate that broadband and internet usage exhibit diminishing returns on total product revenue in the case of imports, while mobile subscriptions show diminishing returns for exports. Specifically, for product exports, the rate of growth begins to slow after reaching an optimal level of ICT use, reflecting the phenomenon of harvesting returns. Although mobile subscriptions have not yet reached their peak, the findings suggest that product exports may decline once this peak is achieved after an appropriate period. Similarly, for product imports, the rate of growth decreases once the optimal level of ICT use is surpassed. However, broadband and internet usage have not yet reached their respective peaks. The results imply that product imports are likely to decline when these thresholds are eventually reached after sufficient time. The consistency of these findings across different estimation methods adds robustness to the analysis. The results from Table 3 align closely with those derived from the Hausman-Taylor estimation in Table 4, further confirming that ICT exerts a strong positive influence on both product exports and imports in G20 economies.

Overall, these findings underscore the importance of understanding the optimal levels of ICT adoption to maximize trade benefits. Policymakers and businesses can use this knowledge to strategically invest in ICT infrastructure while being mindful of potential diminishing returns that may arise beyond certain thresholds. This nuanced understanding is critical for fostering sustainable trade growth in an increasingly digital global economy.

$$EXG_{ijt}\left(\text{optimal level}\right)=\frac{-MOB_1}{2MOB_2}=\frac{-0.609}{2\left(-0.0394\right)}=7.728426; \tag{12}$$

$$IMG_{ijt}\left(\text{optimal level}\right)=\frac{-BRD_1}{2BRD_2}=\frac{-0.241}{2\left(-0.0166\right)}=7.259036; \tag{13}$$

$$IMG_{ijt}\left(\text{optimal level}\right)=\frac{-INT_1}{2INT_2}=\frac{-0.622}{2\left(-0.0636\right)}=4.889937. \tag{14}$$

4.4. Diminishing marginal return of ICT on trade in service

The research investigates ICT's influence on both goods and services trade, as well as its effects on imports and exports, utilizing principal component analysis. Key findings include that ICT positively contributes to the expansion of bilateral trade in goods and services among G20 nations. The impact of ICT is particularly pronounced in the services sector. Over time, there is a noticeable trend of increasing service trade alongside a relative decline in commodity trade.

The study identifies two important phenomena such as Diminishing Marginal Returns of ICT (DMRICT) and Increasing Marginal Returns of ICT (IMRICT). For service trade specifically, ICT demonstrates a positive effect on both service exports and imports. A diminishing return effect is observed for broadband subscriptions on service exports. The optimal levels for internet and mobile subscriptions to experience harvesting returns for service exports have not yet been reached. Service trade income is expected to continue expanding as ICT infrastructure develops further. The research employs neural network model analysis to delve deeper into ICT's impact on both imports and exports. This approach provides nuanced insights into the complex relationship between technological advancement and trade patterns.

These findings have significant policy implications, suggesting that tailored ICT development strategies could effectively boost international trade. The study underscores the importance of continued investment in ICT infrastructure, particularly for promoting service trade in an increasingly digital global economy.

Overall, this research contributes valuable insights into the dynamic relationship between ICT and international trade, highlighting the need for adaptive policies that can harness the potential of technological advancements to enhance global trade flows.

$$EXS_{ijt}\left(\text{optimal level}\right)=\frac{-INT_1}{2INT_2}=\frac{-0.315}{2\left(-0.0141\right)}=11.17021; \tag{15}$$

$$EXS_{ijt}\left(\text{optimal level}\right)=\frac{-MOB_1}{2MOB_2}=\frac{-0.705}{2\left(-0.0436\right)}=8.084862. \tag{16}$$

Table 3. Marginal returns of ICT on trade in goods and services

	Dependent variable: total trade in goods								
	HT			FE			RE		
$LnBRD_{ijt}$	0.193***			0.195***			0.194***		
	(28.37)			(28.59)			(28.60)		
$LnBRD^2_{ijt}$	–0.0112***			–0.0107***			–0.0103***		
	(–5.95)			(–5.70)			(–5.46)		
$LnINT_{ijt}$		0.557***			0.555***			0.549***	
		(16.18)			(16.13)			(15.91)	
$LnINT^2_{ijt}$		–0.0589***			–0.0582***			–0.0572***	
		(–10.53)			(–10.40)			(–10.21)	
$LnMOB_{ijt}$			0.672***			0.665***			0.690***
			(8.71)			(8.63)			(8.91)
$LnMOB^2_{ijt}$			–0.0359***			–0.0347***			–0.0387***
			(–3.75)			(–3.62)			(–4.03)
$LnGDP_{ijt}$	0.578***	0.637***	0.585***	0.564***	0.629***	0.576***	0.573***	0.635***	0.588***
	(37.61)	(42.90)	(41.26)	(35.52)	(41.14)	(39.67)	(37.47)	(42.76)	(41.48)
RTA_{ijt}	–0.00209	–0.00508	–0.0446**	0.0000268	–0.00355	–0.0433**	0.000454	–0.00193	–0.0398**
	(–0.12)	(–0.28)	(–2.50)	(0.00)	(–0.19)	(–2.42)	(0.03)	(–0.11)	(–2.24)
DST_{ij}	–0.810***	–0.822***	–0.836***	–	–	–	–0.809***	–0.822***	–0.835***
	(–9.78)	(–9.73)	(–9.51)	–	–	–	(–10.43)	(–10.16)	(–10.07)
CNT_{ij}	0.996***	0.979***	1.043***	–	–	–	0.998***	0.979***	1.040***
	(3.13)	(3.01)	(3.09)	–	–	–	(3.35)	(3.15)	(3.26)
LNG_{ij}	0.319*	0.311	0.342*	–	–	–	0.319*	0.311*	0.341*
	(1.65)	(1.58)	(1.67)	–	–	–	(1.76)	(1.65)	(1.76)
Constant	13.49***	11.07***	11.59***	6.747***	4.063***	4.495***	13.61***	11.15***	11.46***
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130
R2				0.518	0.509	0.536			
	Dependent variable: total trade in services								
	HT			FE			RE		
$LnBRD_{ijt}$	0.174***			0.178***			0.172***		
	(29.39)			(29.95)			(28.84)		
$LnBRD^2_{ijt}$	0.0240***			0.0247***			0.0245***		
	(14.63)			(15.03)			(14.75)		
$LnINT_{ijt}$		0.144***			0.141***			0.135***	
		(4.70)			(4.59)			(4.36)	
$LnINT^2_{ijt}$		0.0192***			0.0206***			0.0207***	
		(3.85)			(4.13)			(4.10)	
$LnMOB_{ijt}$			0.0173			0.00782			0.0275
			(0.25)			(0.11)			(0.40)
$LnMOB^2_{ijt}$			0.0527***			0.0546***			0.0510***
			(6.23)			(6.45)			(5.99)
$LnGDP_{ijt}$	0.436***	0.516***	0.502***	0.415***	0.499***	0.488***	0.443***	0.520***	0.506***
	(32.23)	(38.66)	(39.75)	(30.01)	(36.67)	(38.08)	(32.63)	(38.77)	(39.96)
RTA_{ijt}	0.0746***	0.0765***	0.0232	0.0779***	0.0797***	0.0252	0.0721***	0.0748***	0.0239
	(4.75)	(4.72)	(1.47)	(4.96)	(4.91)	(1.60)	(4.55)	(4.58)	(1.51)
DST_{ij}	–0.883***	–0.906***	–0.926***	–	–	–	–0.882***	–0.906***	–0.926***
	(–9.65)	(–9.83)	(–9.57)	–	–	–	(–11.59)	(–11.42)	(–10.35)
CNT_{ij}	0.212	0.188	0.234	–	–	–	0.211	0.187	0.232
	(0.60)	(0.53)	(0.63)	–	–	–	(0.72)	(0.61)	(0.67)
LNG_{ij}	1.191***	1.173***	1.240***	–	–	–	1.190***	1.172***	1.239***
	(5.57)	(5.45)	(5.48)	–	–	–	(6.69)	(6.33)	(5.93)
Constant	16.26***	13.96***	14.21***	9.130***	6.497***	6.489***	16.07***	13.87***	14.07***
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130
R2				0.601	0.575	0.604			

Note: ***, **, and * mean significance at the level of 1%, 5%, and 10%, respectively.

Table 4. Marginal returns of ICT on export/import in goods

	Dependent variable: export in goods								
	HT			FE			RE		
$LnBRD_{ijt}$	0.188***			0.189***			0.190***		
	(20.52)			(20.55)			(20.77)		
$LnBRD^2_{ijt}$	0.00433*			0.00459*			0.00570**		
	(1.70)			(1.80)			(2.24)		
$LnINT_{ijt}$		0.279***			0.279***			0.267***	
		(5.97)			(5.97)			(5.71)	
$LnINT^2_{ijt}$		–0.00996			–0.00984			–0.00761	
		(–1.31)			(–1.29)			(–1.00)	
$LnMOB_{ijt}$			0.609***			0.610***			0.633***
			(5.61)			(5.62)			(5.83)
$LnMOB^2_{ijt}$			–0.0394***			–0.0397***			–0.0431***
			(–2.93)			(–2.95)			(–3.20)
$LnGDP_{ijt}$	0.665***	0.737***	0.780***	0.656***	0.736***	0.782***	0.656***	0.733***	0.782***
	(32.24)	(36.77)	(39.41)	(30.59)	(35.44)	(38.28)	(32.04)	(36.62)	(39.58)
RTA_{ijt}	–0.0583**	–0.0543**	–0.0759***	–0.0571**	–0.0541**	–0.0762***	–0.0515**	–0.0471*	–0.0667***
	(–2.39)	(–2.20)	(–3.02)	(–2.34)	(–2.19)	(–3.03)	(–2.12)	(–1.92)	(–2.67)
DST_{ij}	–0.862***	–0.878***	–0.887***	–	–	–	–0.860***	–0.877***	–0.885***
	(–8.56)	(–8.47)	(–8.33)	–	–	–	(–9.04)	(–8.74)	(–8.61)
CNT_{ij}	1.147***	1.126***	1.125***	–	–	–	1.149***	1.126***	1.120***
	(2.96)	(2.82)	(2.75)	–	–	–	(3.14)	(2.92)	(2.83)
LNG_{ij}	0.503**	0.486**	0.514**	–	–	–	0.503**	0.486**	0.513**
	(2.14)	(2.01)	(2.07)	–	–	–	(2.27)	(2.07)	(2.14)
Constant	10.43***	8.098***	5.942***	3.084***	0.420	–1.900***	10.63***	8.218***	5.811***
	(9.75)	(7.42)	(5.23)	(5.24)	(0.73)	(–3.07)	(10.35)	(7.72)	(5.24)
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130
R2				0.441	0.426	0.417			
	Dependent variable: import in goods								
	HT			FE			RE		
$LnBRD_{ijt}$	0.241***			0.530***			0.241***		
	(25.23)			(4.86)			(25.41)		
$LnBRD^2_{ijt}$	–0.0166***			–0.00359			–0.0155***		
	(–6.25)			(–0.27)			(–5.84)		
$LnINT_{ijt}$		0.622***			0.617***			0.609***	
		(12.72)			(12.61)			(12.42)	
$LnINT^2_{ijt}$		–0.0636***			–0.0615***			–0.0610***	
		(–8.01)			(–7.73)			(–7.67)	
$LnMOB_{ijt}$			0.548***			0.247***			0.587***
			(5.03)			(25.68)			(5.35)
$LnMOB^2_{ijt}$			–0.00723			–0.0154***			–0.0133
			(–0.53)			(–5.80)			(–0.98)
$LnGDP_{ijt}$	0.515***	0.586***	0.496***	0.470***	0.561***	0.479***	0.513***	0.583***	0.507***
	(24.30)	(28.36)	(25.17)	(22.89)	(25.82)	(21.39)	(24.41)	(28.35)	(25.75)
RTA_{ijt}	–0.000621	–0.000761	–0.0577**	–0.0539**	0.00381	0.00487	0.00243	0.00327	–0.0499**
	(–0.02)	(–0.03)	(–2.29)	(–2.14)	(0.15)	(0.19)	(0.10)	(0.13)	(–1.99)
DST_{ij}	–0.794***	–0.807***	–0.827***	–	–	–	–0.792***	–0.806***	–0.825***
	(–8.87)	(–8.96)	(–8.67)	–	–	–	(–9.43)	(–9.37)	(–9.46)
CNT_{ij}	0.968***	0.949***	1.045***	–	–	–	0.969***	0.949***	1.037***
	(2.81)	(2.74)	(2.85)	–	–	–	(3.00)	(2.87)	(3.09)
LNG_{ij}	0.312	0.298	0.346	–	–	–	0.312	0.297	0.343*
	(1.49)	(1.42)	(1.55)	–	–	–	(1.59)	(1.48)	(1.69)
Constant	14.37***	11.55***	13.30***	6.774***	5.134***	8.373***	14.43***	11.63***	12.94***
	(14.42)	(11.57)	(12.62)	(10.88)	(8.49)	(13.61)	(15.12)	(12.01)	(13.01)
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130
R2				0.381	0.340	0.360			

Note: ***,**, and * mean significance at the level of 1%, 5%, and 10%, respectively.

Table 5. Marginal returns of ICT on export/import in service

	Dependent variable: export in services								
	HT			FE			RE		
$LnBRD_{ijt}$	0.146***			0.149***			0.147***		
	(22.22)			(22.60)			(22.07)		
$LnBRD^2_{ijt}$	0.0124***			0.0129***			0.0135***		
	(6.79)			(7.07)			(7.33)		
$LnINT_{ijt}$		0.315***			0.313***			0.303***	
		(9.62)			(9.55)			(9.15)	
$LnINT^2_{ijt}$		–0.0141***			–0.0131**			–0.0119**	
		(–2.65)			(–2.46)			(–2.21)	
$LnMOB_{ijt}$			0.705***			0.699***			0.717***
			(9.40)			(9.31)			(9.53)
$LnMOB^2_{ijt}$			–0.0436***			–0.0423***			–0.0454***
			(–4.68)			(–4.54)			(–4.86)
$LnGDP_{ijt}$	0.545***	0.585***	0.601***	0.528***	0.573***	0.591***	0.545***	0.586***	0.604***
	(36.27)	(41.02)	(43.36)	(34.32)	(39.36)	(41.91)	(36.25)	(40.92)	(43.51)
RTA_{ijt}	0.0754***	0.0691***	0.0360**	0.0780***	0.0713***	0.0374**	0.0738***	0.0686***	0.0373**
	(4.31)	(3.98)	(2.07)	(4.46)	(4.11)	(2.16)	(4.19)	(3.93)	(2.15)
DST_{ij}	–0.890***	–0.910***	–0.922***	–	–	–	–0.889***	–0.910***	–0.922***
	(–9.49)	(–9.46)	(–9.29)	–	–	–	(–11.24)	(–10.91)	(–9.72)
CNT_{ij}	0.138	0.129	0.148	–	–	–	0.139	0.130	0.146
	(0.38)	(0.35)	(0.39)	–	–	–	(0.46)	(0.40)	(0.40)
LNG_{ij}	1.301***	1.294***	1.331***	–	–	–	1.301***	1.294***	1.330***
	(5.94)	(5.76)	(5.74)	–	–	–	(7.03)	(6.64)	(6.00)
Constant	12.65***	11.15***	9.493***	5.328***	3.526***	1.708***	12.64***	11.14***	9.396***
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130
R^2				0.534	0.543	0.549			
	Dependent variable: import in services								
	HT			FE			RE		
$LnBRD_{ijt}$	0.183***			0.190***			0.179***		
	(25.24)			(26.05)			(24.35)		
$LnBRD^2_{ijt}$	0.0344***			0.0356***			0.0345***		
	(17.11)			(17.66)			(16.91)		
$LnINT_{ijt}$		–0.0238			–0.0306			–0.0332	
		(–0.63)			(–0.80)			(–0.86)	
$LnINT^2_{ijt}$		0.0500***			0.0526***			0.0512***	
		(8.07)			(8.49)			(8.17)	
$LnMOB_{ijt}$			–0.332***			–0.350***			–0.316***
			(–3.87)			(–4.08)			(–3.66)
$LnMOB^2_{ijt}$			0.0993***			0.103***			0.0966***
			(9.33)			(9.66)			(9.00)
$LnGDP_{ijt}$	0.321***	0.425***	0.415***	0.284***	0.393***	0.389***	0.340***	0.435***	0.425***
	(19.43)	(25.76)	(26.28)	(16.76)	(23.23)	(24.11)	(20.56)	(26.35)	(26.81)
RTA_{ijt}	0.0757***	0.0833***	0.0226	0.0814***	0.0892***	0.0264	0.0719***	0.0804***	0.0234
	(3.93)	(4.13)	(1.14)	(4.22)	(4.42)	(1.33)	(3.69)	(3.97)	(1.18)
DST_{ij}	–0.874***	–0.900***	–0.924***	–	–	–	–0.873***	–0.900***	–0.923***
	(–8.65)	(–9.08)	(–8.93)	–	–	–	(–10.73)	(–10.73)	(–10.03)
CNT_{ij}	0.371	0.337	0.383	–	–	–	0.366	0.335	0.379
	(0.96)	(0.88)	(0.96)	–	–	–	(1.17)	(1.04)	(1.07)
LNG_{ij}	1.152***	1.127***	1.210***	–	–	–	1.150***	1.126***	1.208***
	(4.88)	(4.86)	(5.01)	–	–	–	(6.05)	(5.75)	(5.62)
Constant	18.57***	15.91***	16.49***	11.93***	8.907***	9.152***	18.05***	15.63***	16.20***
Obs.	5130	5130	5130	5130	5130	5130	5130	5130	5130
R^2				0.492	0.446	0.471			

Note: ***,**, and * mean significance at the level of 1%, 5%, and 10%, respectively.

5. Conclusions and limitation

In this study, we have conducted a comprehensive analysis of the impact of ICT on global trade dynamics within G20 economies. Our findings reveal that ICT technology plays a significant role in promoting economic growth and trade. Specifically, we found that ICT progress contributes approximately 0.33% to overall economic growth, with product trade expanding by about 0.12% and service trade by around 0.14%. This underscores the vital importance of digital transformation in driving productivity, innovation, and trade.

Furthermore, our analysis identified a phenomenon known as "Diminishing Marginal Returns of ICT on Trade". This indicates that while the initial adoption of ICT leads to substantial increases in trade volumes, the rate of trade growth diminishes over time as the technology matures. This finding aligns with the theoretical framework of diminishing marginal utility, suggesting that policymakers and businesses must be cognizant of the diminishing returns associated with ICT investments as they scale.

Overall, this research contributes important meaning into the complex nexus between ICT and trade, highlighting both the opportunities and challenges that arise from digital transformation in the global economy.

As ICT development exhibits diminishing returns, countries lagging in digital infrastructure may have an opportunity to catch up more rapidly, provided they implement effective policies. This aligns with Koutroumpis's (2018) observation that broadband adoption has a particularly strong impact on less well-connected regions.

Policymakers should prioritize investments in ICT infrastructure to enhance connectivity and facilitate trade. This includes improving internet access, expanding broadband networks, and supporting the development of mobile technologies. Establishing regulatory frameworks that promote digital trade and address challenges related to data privacy and security is essential. Such frameworks will help create an environment conducive to e-commerce and digital transactions, fostering trade. Businesses must embrace digital technologies to improve operational efficiency and competitiveness in the global market. Companies should recognize the diminishing returns associated with ICT investments. Strategic planning is crucial to ensure that the benefits of ICT adoption are maximized while managing resource allocation effectively.

The study's results must be interpreted in light of certain limitations. The focus on G20 economies, while providing insights into major global players, may not fully capture the dynamics in developing economies. Additionally, the rapid pace of technological change means that the specific ICT measures used in this study may not fully capture emerging technologies like artificial intelligence and blockchain, which could reshape trade dynamics in the future.

Future research should delve into the variability of ICT impacts across different sectors and regions. Understanding how specific ICT applications influence trade can provide deeper insights into optimizing digital strategies. Conducting longitudinal studies that examine the long-term effects of ICT on trade dynamics will be vital in understanding the evolving landscape of global trade in the digital age.

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Author contributions

N. R. Park contributed to data collection, investigation, software, formal analysis, writing – original draft preparation. C. H. Choi contributed to conceptualization, methodology, data curation, writing – review and editing, validation, supervision.

Disclosure statement

The authors declare no conflicts of interest.

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APPENDIX

Table A1. Variable and source

Variable	Definition	Source
TRG_{ijt}	TRGijt's total volume of goods trade between the two countries	UN Comtrade database (n.d.)
EXG_{ijt}	goods exported from country i to country j	UN Comtrade database (n.d.)
IMG_{ijt}	goods imported into country i from country j	UN Comtrade database (n.d.)
TRS_{ijt}	Total Service Trade Volume	Organization for Economic Co-operation and Development (2025)
EXS_{ijt}	service exported from country i to country j.	Organization for Economic Co-operation and Development (2025)
IMS_{ijt}	service imported from country j to country i.	Organization for Economic Co-operation and Development (2025)
BRD_{ijt}	number of broadband subscribers per 100 in country i and country j	International Telecommunication Union (n.d.)
INT_{ijt}	number of Internet subscriptions by individual in country i and country j	International Telecommunication Union (n.d.)
MOB_{ijt}	mobile subscriber count per 100 in country i and country j	International Telecommunication Union (n.d.)
GDP_{ijt}	gross domestic product	World Bank (n.d.).
DST_{ij}	Distance	CEPII (n.d.)
CNT_{ij}	adjacent (adjacent=1)	CEPII (n.d.)
LNG_{ij}	common language	CEPII (n.d.)
RTA_{ijt}	regional trade agreement	CEPII (n.d.)

Table A2. Descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
LnTRG	5,130	23.002	1.581	18.944	27.250
LnEXG	5,130	22.029	1.814	12.192	26.896
LnIMG	5,130	22.341	1.643	12.867	27.057
LnTRS	5,130	21.431	1.711	15.690	25.798
LnEXS	5,130	20.667	1.749	14.800	25.351
LnIMS	5,130	20.685	1.767	13.944	25.295
LnBRD	5,130	2.403	1.341	–3.040	3.822
$LnBRD^2$	5,130	7.571	4.549	0.002	14.607
LnINT	5,130	3.865	0.746	0.870	4.566
$LnINT^2$	5,130	15.492	4.880	0.758	20.848
LnMOB	5,130	4.600	0.403	2.061	5.252
$LnMOB^2$	5,130	21.324	3.380	4.248	27.588
LnGDP	5,130	28.136	0.975	26.130	30.694
LnDST	5,130	8.894	0.764	5.838	9.875
CNT	5,130	0.041	0.198	0	1
LNG	5,130	0.099	0.299	0	1
RTA	5,130	0.269	0.444	0	1