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Unlocking Trade Potential: A Stochastic Frontier Gravity Model Analysis of India-Africa Information and Communication Technology (ICT) Goods Trade

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Abstract

This study examines the relatively unexplored domain of Information and Communication Technology (ICT) trade between India and the African Union (AU), applying the Stochastic Frontier Gravity Model (SFGM) to measure the untapped potential and discern factors that impede trade. It points out India's burgeoning role in global ICT trade, with the AU being an increasingly valuable market due to its digital growth and young population. The research identifies India's significant comparative advantage in exporting telecommunication equipment, with a Revealed Comparative Advantage of 3.54, strategically enhancing its position in the global marketplace. The research notes the high trade complementarity index of 0.984 in 2021, indicating a strong synergy between India's export capabilities and the AU's demand, suggesting a beneficial trade relationship. It acknowledges the shift in Africa's ICT import partners, highlighting China's rising influence and the need for India to solidify its market share in Africa strategically.

The SFGM's application to evaluate trade efficiency, considering factors such as GDP, exchange rate, distance, tariff rate, and language, provides insightful conclusions. Positive impacts of GDP, exchange rate, and shared language on bilateral ICT trade are found to be significant. The findings emphasise the importance of strengthening trade ties for economic development and digital transformation in Africa.

Keywords: Information and Communication Technology (ICT); Stochastic Frontier Gravity Model; Trade Efficiency; India; Africa

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Introduction

With its rapid technological development, robust digital infrastructure, and burgeoning Information and Communication Technology (ICT) sector, India has positioned itself as a significant player in the global ICT trade. Its strategic trade endeavours over the years have evolved in response to domestic technological advancements and international trade dynamics (Bankole et al., 2010). Given the role of ICT in socio-economic development and as an enabler for other sectors, understanding the potential of this trade with regions of future growth remains crucial.

The African Union (AU) represents a region of immense growth potential. The continent, dubbed as the 'last frontier' for global growth, has witnessed increasing digitisation, expansion of telecommunication networks, and a surge in demand for ICT goods and services (Bach, 2013; Montague-Mfuni et al., 2023; Manuwa, 2023). Moreover, Africa's demographic advantage, with a significant chunk of its population under 14 years of age, makes it a burgeoning market with an appetite for digital consumption (Manuwa, 2023; The World Bank, World Development Indicators, 2022). India has significant potential to meet this growing demand for ICT goods in Africa. An action plan to set this demand-supply match can lead to mutual benefit for both regions.

Despite the potential, the trade between India and the African Union in the domain of ICT goods remains sub-optimal. There is a plethora of challenges — be it infrastructural, regulatory, or market-oriented. However, there is a palpable sense that the ceiling for this bilateral trade is far from being reached (Mishra, 2018). Thus, the question arises: what is the trade potential for ICT goods between India and the African Union? Understanding this can provide valuable insights for policymakers, trade facilitators, and businesses aiming to capitalise on this potential.

The current study uses the Stochastic Frontier Gravity Model (SFGM) to explore this inquiry. The gravity model, grounded in the Newtonian principle of gravitational force, posits that bilateral trade between two countries is directly proportional to their economic sizes and inversely proportional to the distance between them. The stochastic frontier extension to the gravity model facilitates the analysis of potential trade flows against the observed ones, helping identify inefficiencies and untapped potential.

Using the SFGM, this research aims to:

- Quantify the unexploited trade potential for ICT goods between India and the African Union.
- Identify the underlying factors hindering the realisation of this potential.

This study holds significance in the current international trade paradigm. By uncovering the latent potential and underlying inhibitors, it endeavours to pave the way for a synergistic trade relationship between India and the African Union. Such an alliance may boost the economic prospects of the involved parties and play a pivotal role in Africa's digital transformation journey.

The next section of this study provides a comprehensive review of pertinent literature. Following the literature review, the third section discusses the bilateral trade relationship between India and Africa concerning ICT goods. The fourth section attempts to meticulously outline the stochastic frontier gravity model's specification and elucidate the expected signs of the explanatory variables. Subsequently, the ensuing section critically examines the empirical results derived from the model. It synthesises overarching conclusions drawn from the findings, thereby contributing to a nuanced understanding of the intricate dynamics characterising India-Africa bilateral trade in the realm of ICT goods.

Theoretical Extant and Empirical Foundations

The distinctive bond between India and Africa is rooted in a shared history characterised by a collective struggle against problems associated with colonialism. India's inclusion of Africa in its foreign policy dates back to the 1950s. However, with the beginning of the new millennium, India has reaffirmed the importance of African nations in global governance, trade, and collaboration

(Lunogelo & Baregu, 2013). The essential role of knowledge and technology transfer through trade for economic development is emphasised (Calandro et al., 2010). A key advantage arising from technological transfer is the globalisation of industries, fostering a unified global marketplace. The relationship between India and Africa extends beyond trade and investment to encompass knowledge transfer, skills, and research and development. The inaugural India-Africa Forum Summit, 2008 held in New Delhi marked a significant step in this direction (Lunogelo & Baregu, 2013).

In terms of access to knowledge, ICT plays a crucial role. The development of the telecommunications sector in Africa began with various policy reforms, with harmonised ICT policy and regulatory frameworks at the national level being noteworthy (Calandro, 2010). Beyond individual efforts to expand ICT access globally, a widespread revolution occurred worldwide after the COVID-19 pandemic (Chivunga & Tempest, 2021). The substantial shift to digital platforms during this period increased the demand for ICT goods in Africa. Consequently, two major factors contributing to the mass demand for ICT goods in the last two decades are changes in ICT-related regulatory frameworks in Africa and the global pandemic in 2019. Notably, Africa initially imported communication equipment goods from India but has shifted to China at present. China has become deeply involved in the global ICT goods trade, capturing a significant share of the world market (Chan, 2020; UNCTADSTAT, 2023). Both India and China who happen to be among the top ten largest economies in the world 2024, implement various policies over time to enhance their exports in the international market (International Monetary Fund, 2024). One noteworthy policy is the "Duty-Free Tariff Preference" (DFTP) Scheme for the Least Developed Countries (LDCs)1.

However, over five decades ago, in his study, Rajan (1966) highlighted the disparity in economic growth between developed and developing nations for the period 1955-1962, with African and Far Eastern countries showing notably lower income levels. This backdrop underlines the importance of reversing trends like diminishing global export shares and worsening trade terms for developing countries. The research aligns with exploring trade potential and barriers through the lens of preferential tariffs, as historical examples and United Nations Conference on Trade and Development's (UNCTAD) emphasis suggest such tariffs could significantly aid developing countries by diversifying and expanding their export bases. This context enriches the study's objectives by grounding the analysis in historical economic challenges and responses, thereby providing a broader perspective on the potential impact of preferential trade policies between India and Africa in the ICT sector.

In a similar context, Atif et al. (2017) emphasise the importance of understanding economic conditions and export-facilitating factors for successful export strategies. Other scholars like Sevela (2002) and Olper & Raimondi (2008) use the gravity model to explore determinants of exports, highlighting the role of Gross National Income (GNI) and the negative impact of distance and trade barriers. This highlights the gravity model's utility in identifying export influences yet points to its limitations in capturing unquantifiable trade obstacles. Nevertheless, the traditional gravity model faces limitations in effectively addressing the various barriers to trade, as many of these impediments are challenging to quantify. Consequently, these barriers are incorporated into the unobserved disturbance term (Baier & Bergstrand, 2009). In this case, the stochastic frontier gravity model can be applied to capture unobservable resistance to trade (Devadason & Chandran, 2019; Nguyen & Wu, 2020). In another study, Hassan (2017) this methodology for identification of the factors, including 'behind the border constraints', that affect Bangladesh's

[1] The "Duty-Free Tariff Preference" (DFTP) Scheme targets the economic upliftment of the world's impoverished nations, the Least Developed Countries (LDCs), by providing them with duty-free entry into the markets of wealthier countries.

exports. The results obtained are found to enhance trade integration and unlock untapped export potentials significantly. This narrative aligns with our objectives, leveraging the Stochastic Frontier Gravity Model to explore similar determinants and barriers in India-Africa ICT goods trade, aiming to quantify untapped potential and identify facilitative and obstructive factors in expanding this trade relationship.

The review of existing literature reveals a notable gap in research concerning the trade of ICT goods between India and African countries. In reality, there is a lot of trade between India and African countries, but this volume seems very small when we talk about ICT goods. Moreover, there is a lack of comprehensive analysis on how India's ICT goods offerings align with the demands of the African market. This oversight in the literature suggests that a thorough investigation into the untapped potential of bilateral trade in this sector could provide valuable insights. By exploring the synergies and mismatches between India's ICT goods production capabilities and the needs of the African market, such research could significantly contribute to understanding and optimising the economic interactions between these two regions.

Strategic Alignment: The African Union's Role in Facilitating Growth in India's ICT Trade
India's Strength (Supply Side)

The division of ICT goods, comprising 94 distinct products categorised under six-digit HS codes (2017),2 represents a comprehensive spectrum of technological products that shape the modern information and communication landscape. These goods are organised into five key categories: Computers and peripheral equipment, Communication equipment, Consumer electronic equipment, Electronic components, and Miscellaneous (UNCTAD, 2018). This systematic classification allows for a precise assessment of the comparative advantage of nations in each category and enables policymakers and industry leaders to strategically target their efforts in the global ICT market.

The original categorisation of ICT goods was established in the OECD's 2011 Guide to Measuring the Information Society. Data for these goods are submitted by national authorities, with product specifics categorised according to the World Customs Organization's Harmonized Commodity Description and Coding System for various years: HS 1992, HS 1996, HS 2002, HS 2007, HS 2012, HS 2017, or HS 2022, varying by the reporting country and the year of the report. Figure 1 shows an overview of India's ICT goods export to the world, contrasting with the total merchandise exports.

Figure 1 illustrates that while India's exports of ICT goods are growing and are a significant part of the export economy, they represent a smaller segment compared to the total goods export values. The sharp rise in ICT goods exports since 2017 indicates a strong recovery or growth phase for India's ICT goods export sector.

India exhibits a compelling comparative advantage in exporting telecommunication equipment, primarily due to its remarkable performance in the Communication equipment category, as demonstrated by a Revealed Comparative Advantage (RCA3) of 3.54 (Table 1). This high RCA signifies India's proficiency in producing and exporting telecommunication equipment more efficiently and competitively compared to other nations. This competitive edge has positioned India as a significant player in the global market for communication technology.

[2] The OECD initially defined the list of ICT goods using the Harmonised System (HS) 2007 version. This definition underwent revisions in 2010 and was later updated to conform to the HS 2012 and HS 2017 versions by UNCTAD, in collaboration with UNSD. The latest version of the list includes 94 goods, detailed at the HS 2017 version's 6-digit level shown in Appendix 1.

[3] A detailed explanation of RCA calculation is shown in the "Methodology and Model Specification" section.

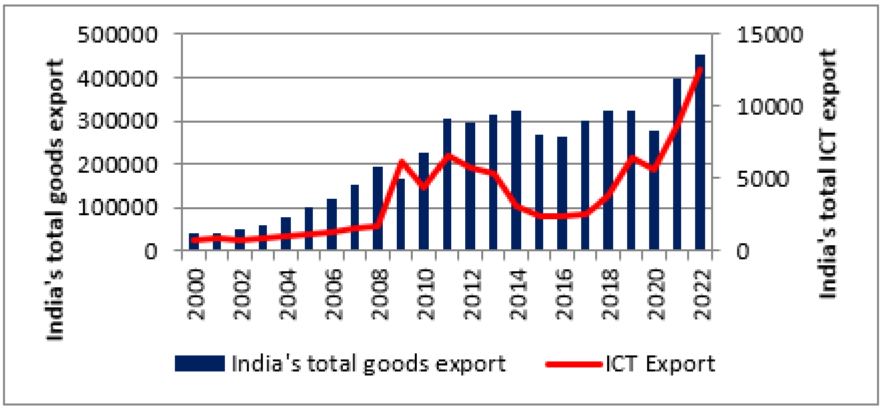


Figure 1: India's Total Merchandise Goods Export and Total ICT Goods Export to the World (US dollars at Current Prices in Millions)
Source: Authors' Calculation

Table 1: RCA Value of India in ICT Subcategories in 2021

Economy	Computers and Peripheral Equipment	Communication Equipment	Consumer Electronic Equipment	Electronic Component	Miscellaneous
India	0.37	3.54	0.32	0.25	0.92

Source: Authors' Calculation Utilising UNCTADSTAT Database

According to India Cellular and Electronics Association (ICEA) 2018 report, at its zenith in 2011, India manufactured 155 million handsets, of which 105 million were exported. This substantial production was primarily attributed to Nokia's manufacturing operations in the country. However, in the subsequent years, India's mobile manufacturing sector witnessed a rapid decline, producing only 58 million handsets in 2014, with zero exports, following the closure of the Nokia plant due to tax disputes and the inability to attract other mobile manufacturers.

India is gradually reclaiming its standing as a global manufacturer of mobile devices and components. ICEA (2018), in their report, reveals that since 2014, approximately 120 manufacturing units have been established, driven by the introduction of the Phased Manufacturing Program (PMP) and spurred by robust domestic market demand. In 2017, India manufactured 225 million mobile phones valued at USD 20 billion, with exports reaching around USD 0.1 billion. However, with the domestic market showing signs of saturation, there is a shift in focus from "Making in India for India" to "Making in India for the world." If India extends its ambitions to the export market, projections suggest the potential to manufacture around 1,250 million handsets by 2025. This envisioned expansion could invigorate an industry valued at approximately USD 230 billion, simultaneously generating over 4.7 million jobs, particularly in Assembly, Programming, Testing, and Packaging (APTP) operations and PMP sub-assembly operations.

Africa's Demand for ICT Goods

The import data in Table 2 indicates that low-income nations import a substantially higher proportion of communication equipment than other types of ICT goods. In the global context, communication equipment accounts for 21.27% of ICT imports, while in low-income economies, this figure rises substantially to 45.17%. This underlines the importance of addressing the specific needs of low-income countries in the telecommunication sector, where India's competitive advantage can be instrumental in providing affordable and efficient solutions.

Table 2: Import of ICT Goods in 2021 by Economies of Different Income Groups (%)

ECONOMY	Computers and Peripheral Equipment	Communication Equipment	Consumer Electronic Equipment	Electronic Components	Miscellaneous
World	22.82	21.27	6.92	44.59	4.40
Low-income economies	23.43	45.17	14.21	11.40	5.78
Lower-middle-income Economies	22.68	28.65	6.75	36.35	5.57
Upper-middle-income Economies	14.79	13.03	3.13	64.37	4.68
High-income Economies	26.59	24.66	8.71	35.86	4.19
High-income OECD Members	34.14	27.59	12.18	21.20	4.89
High-income non-OECD Members	13.45	19.56	2.66	61.35	2.98

Source: Authors' Calculation Utilising UNCTADSTAT Database
Note: UNCTAD classification has been followed to categorise the economies under different heads

Table 3: Import of ICT Goods by Different Economic Groups in 2021 (%)

ECONOMY	African Union	ASEAN	ASEAN plus China, Japan, and the Republic of Korea	G20 (Group of Twenty)
Computers and Peripheral Equipment	26.30	12.51	12.99	26.34
Communication Equipment	44.19	12.24	11.82	21.84
Consumer Electronic Equipment	10.01	3.03	2.86	8.28
Electronic Components	12.40	69.04	68.43	38.59
Miscellaneous	7.11	3.18	3.90	4.95

Source: Authors' Calculation Utilising UNCTADSTAT Database

The statistics shown in Table 2 on import patterns in various income groups confirm the potential of African countries as viable export destinations for India's telecommunication equipment. African countries, classified under the "African Union" economy, exhibit a substantial 44.19% share of imports in the Communication equipment category. This exceeds the import shares of the ASEAN (Association of Southeast Asian Nations)[4], the ASEAN plus China, Japan, the Republic of Korea, and even the G20 nations,[5] further emphasising the attractiveness of the African Union as a

[4] Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam

[5] Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, United Kingdom, United States, European Union

target market for Indian telecommunication equipment exports (Table 3).

Bridging Gaps: India's Untapped Potential to Fulfil Africa's Communication Equipment Demand

While India's ICT exports primarily target Asian countries (51.66%) and European nations (30.19%), the African continent receives a relatively modest share of only 4.07%. This low share represents a remarkable opportunity for India to explore and expand its African market presence. The African Union, in particular, emerges as an attractive market due to its rapid economic growth and the increasing need for advanced telecommunication solutions to support regional development and connectivity.

India's current export destinations for ICT goods reveal the need for diversification and expansion. The United Arab Emirates and the United States of America dominate the majority share of India's ICT goods exports, with shares of 24.49% and 12.44%, respectively, as shown in Table 4. This concentration highlights the need to explore new markets and reduce reliance on a few key destinations. The growing demand for ICT goods in Africa, combined with India's comparative advantage in the communication equipment category, presents a compelling case for India to increase its engagement with the African Union.

Table 4: India's Top 10 ICT Export Destinations

Countries	Share in 2021 (%)
United Arab Emirates	24.49
United States of America	12.44
China	7.81
United Kingdom	5.78
Netherlands	5.52
Russian Federation	4.73
Germany	4.44
Hong Kong SAR	2.97
Japan	2.38
France	2.10

Source: Authors' Calculation Utilising UNCTADSTAT Database

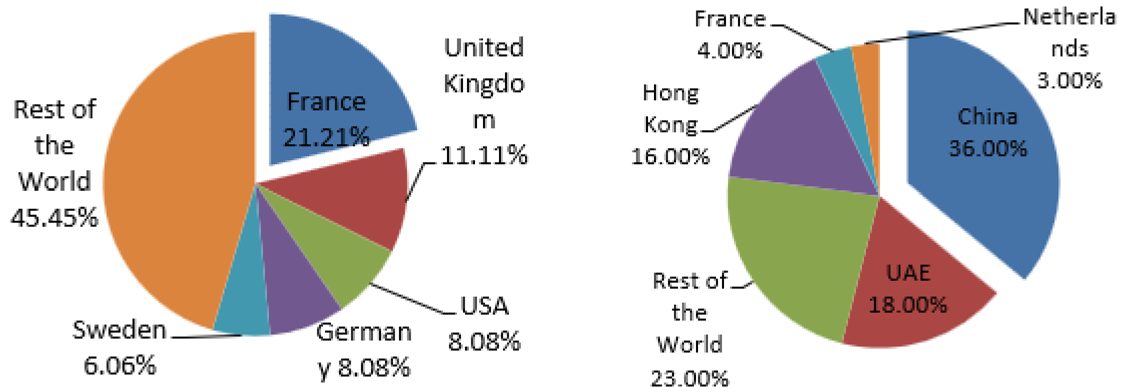
Before examining the potential for bilateral trade, it is crucial to align the demand and supply of goods to be exchanged by both parties. The Trade Complementarity Index6 (TCI) illustrates the degree of concordance in the types of ICT products traded between India and African countries. With a range of zero to one, a value close to one signifies a high alignment of products within the category and vice versa. A notably high TCI (0.984) between India and Africa is found, reinforcing the rationale for India to expand its export of ICT goods to the African continent. Given India's comparative advantage in telecommunication equipment, this significant trade complementarity emphasises the natural compatibility between India's strengths and the demands of the African Union.

While India's leading export destinations are mainly the Middle East and West, the import destinations of African countries are southeast countries.

The distribution of Africa's import partners for ICT goods underwent notable changes from 2000 to 2021. In 2000, France led the import landscape, with the United Kingdom, the United States of America, Germany, and Sweden also playing significant roles. Fast forward to 2021,

[6] A detailed explanation regarding the formula of TCI is presented in "Methodology and Model Specification" section.

China emerged as the major import partner, accompanied by the United Arab Emirates and Hong Kong. This shift marked a diversification of import sources, evident in a substantial "Rest of the World" category (Figure 2). The dynamics indicate a transformation in Africa's trade relationships, reflecting the evolving global economic landscape and the emergence of new players in the ICT sector. However, from 2009 to some consecutive years, India was Africa's significant ICT trade partner. This can be seen from Figure 3.



2000 **2021**

Figure 2: Change in Africa's Import Partners for ICT goods in 2000 and 2021
Source: Author's Calculation Utilising UNCTADSTAT Database

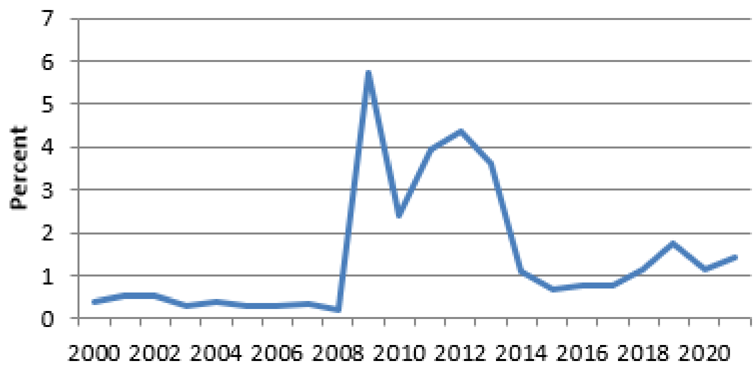


Figure 3: India's Share in Africa's Import of ICT Goods (%)
Source: Authors' Calculation Utilising UNCTADSTAT Database

The provided data (Figure 3) represents India's annual share of Africa's import of ICT goods from the year 2000 to 2021. The values, ranging from 0.39% in 2000 to 1.42% in 2021, indicate the proportion of Africa's total ICT imports that can be attributed to India each year. The giant hike of India's share in 2009 can be attributed to some of India's foreign economic policies during this time. As per Gakhar & Gokarn (2015), the Confederation of Indian Industry (CII) has organised a total of nine India-Africa Conclaves since the inaugural Conclave in New Delhi in 2005. Over the years, both the number of participants and project opportunities have significantly increased. During the second India-Africa Forum Summit in 2011, India announced its commitment to provide Lines of Credit (LOCs) amounting to $5-4 billion until 2014, aiming to support the developmental needs of its African partners. These triennial Summits, initiated in 2008, reveal the growing significance of India-Africa relations, bringing together top leaders from India and African countries to engage in structured political and economic interactions. Notably, in 2008, India declared the implementation of a noteworthy initiative – the "Duty-Free Tariff Preference (DFTP) Scheme for the Least Developed Countries" (DFTP Scheme for LDCs). The primary objective of this scheme is to grant tariff preferences to the exports from least developed countries when imported into India for least developed countries (UNCTAD, 2017). This encouraged a massive growth in India's ICT export to African countries in 2009, which can be witnessed in Figure 2 (Lunogelo & Baregu, 2013). However, the fluctuating percentages suggest dynamic changes in the trade relationship between Africa and India over the two decades. While there are periods of increased and decreased shares, the overall trend demonstrates India's varying influence on Africa's ICT import market during this period.

In summary, India's comparative advantage in exporting telecommunication equipment, particularly in the Communication equipment category, positions the nation favourably in the global market. The African Union, with its growing economy and significant demand for advanced communication technology, emerges as a compelling export destination for India. Given the underrepresentation of Indian ICT exports in the African continent and the import patterns in low-income economies, India should strategically explore and expand its presence in the African Union to leverage its comparative advantage and contribute to the region's digital development and economic growth. This move would not only strengthen India's global ICT market position but also foster enhanced cooperation between India and African Union countries in the realm of telecommunications.

Methodology and Model Specification

RCA is a metric used to assess a country's specialisation in certain industries based on its export patterns. It indicates the extent to which a nation's exports in a particular sector exceed what would be expected given the global production distribution. This study uses the RCA formula Balassa (1965) proposed. The formula is as follows:

$$Bij = (Xij/Xiict) / (Xwj/Xwict) \ \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where,
Xij = 'i' (India's) exports of ICT good (ict) 'j'.
Xiict = 'i' (India's) exports of total ICT goods (ict).
Xwj = 'w' (World's) exports of ICT good (ICT) j.
Xwict = 'w' (World's) exports of total ICT goods (ict).

Another index called "Trade Complementarity Index" (TCI) is used to measure the match between India's supply and Africa's demand for ICT goods. TCI shows how well one nation's export trends line up with another's import trends. A high level of complementarity is seen to signal better chances for a fruitful trade agreement (Mikic & Gilbert, 2007). The formula for calculating TCI is adopted from "Trade Statistics in Policymaking: A of Commonly Used Trade Indices and Indicators" (Mikic & Gilbert, 2007). The formula is as follows:

$$TCI = \left(1 - \left(\sum \left|\frac{\sum_w m_{iwd}}{\sum_w M_{wd}} - \frac{\sum_w x_{isw}}{\sum_w X_{sw}}\right|\right) \div 2\right) \times 100$$

Where 'x' is the commodity export flow, 'X' is the total export flow, 'm' is the commodity import flow, and 'M' is the total import flow; 'd' is the interested importing country; 's' is the interested exporting country; 'w' is the set of all countries in the world; 'i' is the set of industries. In other words, we add up the absolute value of the difference between a country's sectoral import share and its sectoral export share from another.

The fundamental gravity model of trade can be enhanced by incorporating additional variables that explain trade, allowing for a more comprehensive analysis of bilateral trade flows. Bergstrand (1985) demonstrated this in his research by including exchange rates to account for variations in international trade. According to existing literature and theories on trade, a variety of other explanatory variables related to trade can be integrated into the model. This includes factors like the average tariff rate or dummy variables that signify the presence of a trade agreement, a shared border, or a common language between two trading nations. These variables are added to the basic model understand better the trade dynamics between the countries. Consequently, an equation representing the expanded gravity model for exports could be structured to include these variables.

$$lnBT_{ij} = \beta_0 + \beta_1 lnGDP_i + \beta_2 lnGDP_j + \beta_3 lnExchange\ Rate_{ij} + \beta_4\ lnIND\ Import\ Tariff_i + \beta_5\ lnAfrica\ Import\ Tariff_j + \beta_6 LANG_{ij} + \beta_7 lnDIST_{ij} + \beta_8 D1_j + \beta_9 D2_{ij} + \varepsilon ij \ldots..(1)$$

The conventional gravity model is designed to calculate the average impact of trade determinants and can account for measurable trade resistance factors, like distance, and formal trade restrictions, such as tariffs. However, it does not effectively account for more subjective and challenging-to-measure barriers, including specific country, socio-political, and institutional constraints that exist behind a country's borders, as noted by scholars like Armstrong (2007) and Kalirajan (2007). Due to the exclusion of these unseen trade barriers, the model's assumption that the error term εij follows a normal distribution is compromised, resulting in heteroskedasticity, as discussed by Kalirajan & Finlay (2005).

For this study, we apply Stochastic Frontier Analysis (SFA), which is a well-established method for assessing firm performance. Originally developed independently by Aigner et al. (1977) and Meeusen & van Den Broeck in 1977, it has been widely used in this regard. SFA involves establishing a production frontier representing the maximum achievable output given certain input levels. Efficient firms operate on this frontier, achieving a perfect match between observed and potential output. Inefficient firms, on the other hand, operate within the frontier, indicating a gap between what is observed and what could be achieved with the same inputs. This suggests room for output expansion with existing resources. In the context of production, technical inefficiency is the extent to which actual output falls short of its potential. SFA can also be applied to trade performance, where inefficient trade reflects a shortfall compared to the ideal level. This adaptation involves modifying the conventional gravity model.

The stochastic frontier gravity equation for exports can generally be estimated in the following manner:

$$BTij = ln\, f(Zi;\ \beta) exp(-uij + vij)\ldots\ldots..(2)$$

In linear form, this can be written as,

$$ln\, BTij = ln\, f(Zi;\ \beta) - uij + vij\ldots\ldots\ldots\ldots(3)$$

In this formulation, BT_{ij} signifies the trade between countries i and j, while Z_i encapsulates factors that could influence potential bilateral trade, and β denotes unknown parameters. Differing from equation (1), which used a single error term *εij*, equation (3) separates the error into two parts: *uij* and *vij*. Here, *uij* is a one-sided error term reflecting inefficiencies or internal barriers, while *vij* accounts for stochastic errors. Should *uij* deviate from zero, it indicates that internal barriers are preventing trade from achieving its full potential.

Ideally, export potential refers to the export level that could be reached under completely free and smooth trade between two countries. However, such conditions are unattainable in practice. Thus, a country's export potential is considered to be the highest level of exports possible, given the current trade determinants and the minimal level of restrictions present (Armstrong, 2007; Drysdale et al., 2000). In essence, potential trade does not mean trading under perfect free trade scenarios but rather the highest feasible level of trade given the lowest level of restrictions between any two countries.

The difference between actual and potential exports reflects the system's efficiency loss, which can be quantified using the stochastic frontier model (Kalirajan & Finlay, 2005). This efficiency gap may arise from fundamental export determinants and various socio-political and institutional factors within countries that affect trade activities. Based on this perspective, a country's export efficiency level can be determined using a specific equation within the stochastic frontier model. The complete specification of the stochastic frontier model for export determinants between India and African countries is outlined below.

Technical efficiency,

$$TEij = ln\, f(Zi;\, \beta)exp(-uij + vij)/\, ln\, f(Zi;\, \beta)exp(vij) = exp(-uij)\text{........(4)}$$

$$lnBT_{ij} = \beta_0 + \beta_1 lnGDP_i + \beta_2 lnGDP_j + \beta_3 lnExchange\ Rate_{ij} + \beta_4\ lnIND\ Import\ Tariff_i + \beta_5\ lnAfrica\ Import\ Tariff_j + \beta_6 LANG_{ij} + \beta_7 lnDIST_{ij} + \beta_8 D1_j + \beta_9 D2_{ij} - u_{ij} + v_{ij} \dots\dots\dots\dots (5)$$

All explanatory variables undergo a logarithmic transformation (*ln*) in the specified model, except the dummy variables. Here, *i* and *j* denote India and African countries, respectively. *GDP, Exchange rate,* and tariff-related variables are time-variant explanatory variables, while *LANG, DIST,* and dummy variables are vectors of time-invariant explanatory variables.

The dependent variable, *BT*, represents bilateral trade in ICT goods between India and African countries. The explanatory variables encompass key economic, geographical, and policy-related factors. *GDP* denotes the Gross Domestic Product of India and African countries measured in US dollars, respectively. The *Exchange rate* variable reflects the value of African currencies against the Indian Rupee. '*IND Import Tariff*'' and '*Africa Import Tariff'* represent the import tariff rates on non-agricultural and non-fuel products, specified annually, with duty type MNF (most favoured nation). The variable '*LANG*' serves as a dummy variable, capturing the presence of a common language between India and African nations. *DIST* represents the geographical distance between trading partners measured in kilometres. Dummy variables *D1* and *D2* indicate whether the African country falls into the category of least developed countries and the period between 2009 and 2014, respectively. The inclusion of *D2* corresponds to India's adoption of the Duty-Free Tariff Preference (DFTP) Scheme for Least Developed Countries in 2009. The variable v_{ij} denotes statistical noise attributed to measurement error, while the one-sided inefficiency element, represented by u_{ij}, gauges trade performance.

u_{ij} represents the truncated, non-negative, single-sided error term encapsulating the combined impact of economic distance or behind-the-border restrictions in India and African nations that obstruct exports from achieving their potential. Conversely, $exp(u_{ij})$ reflects the proportion of actual versus potential bilateral trade between India and its trading partner country *j*. On the other hand, v_{ij} is the random error term that follows a normal distribution, N(0,σ^2), capturing the influence of variables not included in the model on the independent variable.

Data for ICT trade, exchange rates and tariffs are sourced from the UNCTADSTAT database, while GDP data are obtained from the World Bank database. Language and distance-related information is collected from the CEPII (2022) website, ensuring a comprehensive analysis of the factors influencing bilateral trade dynamics. The period considered for this model is from

2000 to 2021. Table 5 displays the anticipated sign of the variables.

Descriptive statistics of the variables are shown in Table 6. It provides a foundational statistical overview to support the analysis of trade dynamics and the potential for ICT goods trade between India and African countries.

Table 5: Expected Sign of Variables

Variables	Expected Sign
GDP_i	+
GDP_j	+
Exchange Rate	+
IND Import Tariff	-,+
Africa's Import Tariff	-,+
LANG	+
DIST	-
D1	+
D2	+

Table 6: Descriptive Statistics of Logarithmic Transformation of the Variables

Variable	No. of Observations	Mean	Std. Dev.	Min	Max
BTij	1057	-0.36	1.18	-4.66	2.44
GDP_i	1166	12.19	0.17	11.90	12.44
GDP_j	1115	10.07	0.69	8.19	11.71
Exchange Rate	1144	-0.43	2.45	-6.53	4.47
DIST	1122	3.85	0.11	3.60	4.01
IND Import Tariff	1113	2.07	1.12	-1.10	3.47
Africa's Import Tariff	721	2.25	0.60	-1.79	3.48
Source: Authors' Own Calculation					

Results and Discussion

The results of the stochastic frontier gravity model between India and African countries for ICT goods provide valuable insights into the determinants of bilateral trade in this sector. It is shown in Table 7.

The results presented in Table 7 reveal that the variables representing the GDP of both India and Africa exhibit positive and significant correlations. This suggests that as the economies of these nations grow, there is a positive inclination for the bilateral trade of ICT goods. Furthermore, this implies that language and geographical distance significantly impact their mutual trade in the ICT sector. However, in the present era, advancements in ICT enable communication in various languages, mitigating linguistic differences as a potential impediment to trade. Additionally, distance negatively impacts bilateral trade between economies due to transportation costs. Although ongoing developments in transportation infrastructure have reduced the impact of distance on bilateral trade, its impact is still significant. While long distances may increase transportation costs, the ability of a country to offer goods at a comparatively lower cost can offset these expenses.

The negative and significant coefficient for Africa's import tariff complies with the conventional theory that import tariff discourages imports and hence impede bilateral trade (Hassan, 2017). On the other hand, the coefficient for India's import tariff is also negative and statistically significant, implying that India's import tariffs significantly impact bilateral trade in the same way as Africa. However, the implementation of the Duty-Free Tariff Preference (DFTP) Scheme by India for Least Developed Countries (LDCs) in 2009 had pushed the ICT goods trade volumes. The DFTP Scheme appears to have been pivotal in influencing the positive relationship and increased bilateral trade in ICT goods between India and African countries during the specified period. The dummy variable *D2*, representing the period between 2009 and 2014, shows positive and highly significant coefficients, highlighting the positive impact of DFTP on bilateral ICT trade. The exchange rate exhibits a positive and significant coefficient, indicating that an appreciation of the exchange rate of African countries against India positively influences the bilateral trade in ICT goods between India and African countries. In this case, imports become relatively cheaper for domestic consumers, potentially increasing the demand for imported goods. Hence, the devaluation of the Indian currency can improve bilateral trade with African countries in the long run. In the context of Sri Lanka, a study by Thahara et al. (2021) finds that the long-term impact of exchange rates on trade balance is negative, implying that devaluation of the currency could eventually improve the trade balance. This aligns with the J-Curve phenomenon, which posits that an immediate devaluation might not improve the trade balance but could have a favourable impact over time.

Table 7: Results of The Maximum Likelihood Estimation of Stochastic Frontier Gravity Model Between India and African Countries for Bilateral Trade of ICT Goods

Variables	Coefficients
GDP_i	0.68*** (0.28)
GDP_j	1.15*** (0.05)
Exchange Rate	0.02 (0.02)
IND Import Tariff	-0.09*** (0.04)
Africa Import Tariff	-0.17*** (0.05)
LANG	0.20*** (0.07)
DIST	-0.88*** (0.33)
D1	0.00 (0.8)
D2	0.70*** (0.06)
Constant	-15.72*** (3.59)
σ_v^2	-1.87*** (0.15)
σ_u^2	0.06 (0.10)
Lambda	3.486 (0.09)
Log Likelihood : -684.94	
*** shows significance at 1 % level.	
Source: Authors' Calculation	

Trade Efficiency Values

The efficiency scores in Table 8, ranging from 0 to 1, indicate the relative effectiveness of each country in optimising its resources and trade conditions to achieve the maximum potential level of trade.

Table 8: Efficiency values obtained from SFA for 2021

Country	Efficiency Values	Country	Efficiency Values
Morocco	0.83	Namibia	0.51
Gambia	0.74	Zambia	0.51
South Africa	0.74	Zimbabwe	0.50
Togo	0.73	Uganda	0.49
Guinea	0.72	Eswatini	0.48
Liberia	0.66	Mali	0.48
Mauritania	0.66	Botswana	0.46
Mauritius	0.66	Madagascar	0.45
Sierra Leone	0.64	Benin	0.44
Ghana	0.63	Kenya	0.44
Niger	0.63	Angola	0.40
Senegal	0.60	Tanzania	0.38
Seychelles	0.60	Nigeria	0.37
Guinea-Bissau	0.58	Burkina Faso	0.34
Burundi	0.57	Ethiopia	0.28
Cabo Verde	0.54	Libya	0.27
Malawi	0.54	Algeria	0.26
Mozambique	0.53	Comoros	0.10
Rwanda	0.53	Lesotho	0.04

Source: Authors' Calculation

Morocco, Gambia, South Africa, Togo, and Guinea lead the pack with high-efficiency scores of 0.84 to 0.72, showcasing their adeptness in the ICT goods trade. On the other end of the spectrum, Lesotho exhibits a notably lower efficiency score of 0.04, suggesting challenges or inefficiencies in its bilateral trade relationship. The scores serve as valuable benchmarks for policymakers and stakeholders to identify areas for improvement and enhance the overall efficiency of trade collaborations between these countries and India in the ICT sector. Figure 4 shows the efficiency values over 21 years.

Figure 4 illustrates a significant decline in efficiency values over the years for certain countries. Specifically, the efficiency values for Algeria, Angola, Benin, Ethiopia, Nigeria, Tanzania, and Uganda have notably decreased. This decline in efficiency values suggests a shift in these countries' import destinations away from India to other sources.

Currently, the majority of African countries, including those mentioned, predominantly import Information and Communication Technology (ICT) goods, especially telecommunication equipment, from China. However, it is noteworthy that India was an initial key partner in this category of goods, providing an initial impetus. The decline in efficiency values raises the possibility of India losing market share to other suppliers. Reclaiming this market could be instrumental in revitalising India's position and diversifying import sources for the African Union (AU). Such diversification would reduce dependence on a single source, thereby enhancing trade resilience and strategic economic partnerships for the countries involved.

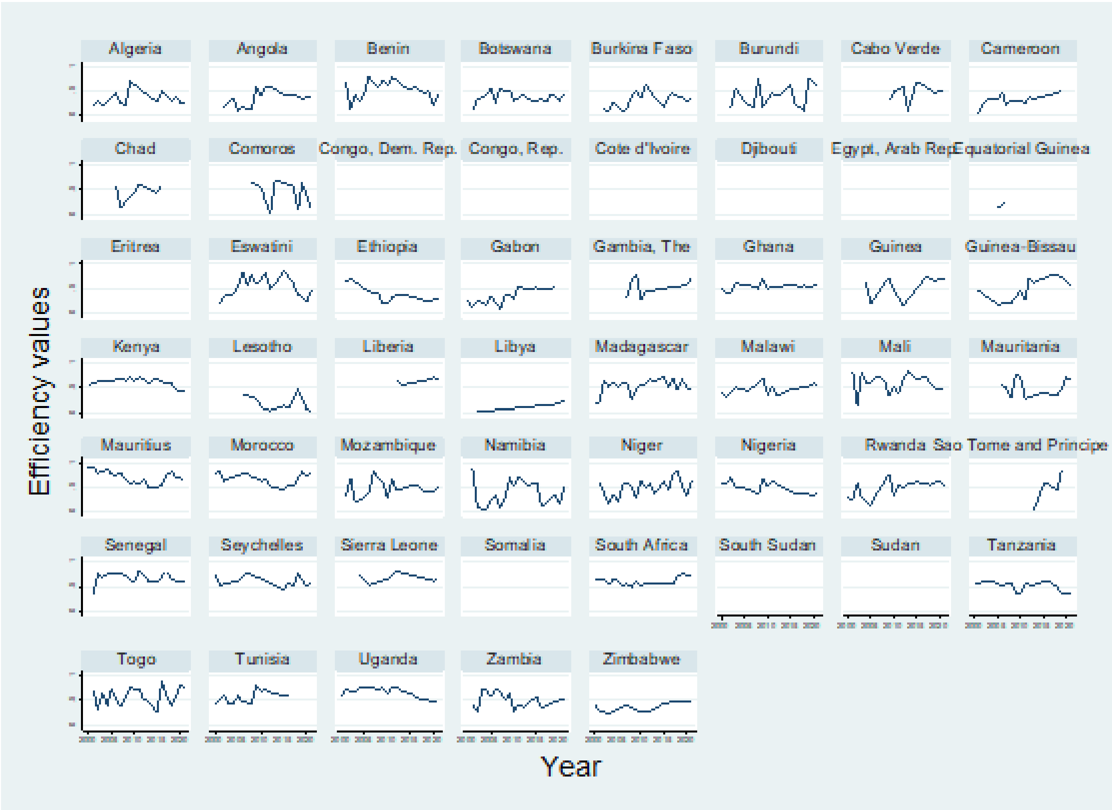


Figure 4: Efficiency Values
Source: Authors' Calculaton

Conclusion

In conclusion, this research examines the trade potential for ICT goods between India and the African Union (AU). As a prominent player in the global ICT trade, India has been exploring opportunities to enhance its trade relations, particularly in the rapidly growing regions of the African continent. With its increasing digitisation and demographic advantage, the AU emerges as a promising market for India's ICT exports. The study employs the Stochastic Frontier Gravity Model to quantify unexploited trade potential and identify inhibiting factors.

The rationale for focusing on the AU as a suitable trade partner for India's ICT goods lies in India's comparative advantage, particularly in exporting telecommunication equipment. The RCA analysis highlights India's proficiency in the communication equipment category, positioning it as a key player in the global market. With its growing economy and significant demand for advanced communication technology, the AU presents a compelling destination for India's ICT exports. The data unveils the need for India to diversify its ICT export destinations, with a strategic emphasis on the African continent. The substantial trade complementarity between India and the AU, as indicated by a high trade complementarity index, reinforces the rationale for expanding ICT exports. The index suggests a natural alignment between India's strengths and the AU's demands, creating a mutually beneficial trade environment. Capitalising on this complementarity can foster a harmonious economic relationship, contributing to the growth and development of both regions.

Analysing Africa's import partners for ICT goods over the years reveals a transformation in trade dynamics, with China emerging as a dominant player. However, India's share in Africa's ICT imports has shown fluctuations, indicating the influence of various factors such as economic developments and geopolitical dynamics. The study emphasises the need for India to strategically enhance its presence in Africa strategically, considering the changing trade landscape.

The outcomes of the Stochastic Frontier Gravity Model offer valuable insights into the factors influencing trade flows between India and the African Union (AU). The presence of a shared language, as indicated by the language variable, has a small but positive impact on the trade of ICT goods. Despite efforts in the ICT sector to mitigate language barriers, having a common language still contributes positively to the bilateral trade in ICT goods between India and African nations. Additionally, tariffs imposed by India and African countries negatively affect the bilateral trade of ICT goods. Notably, India's initiation of the Duty-Free Tariff Preference (DFTP) Scheme for Least Developed Countries (LDCs) in 2009 has played a beneficial role in enhancing ICT trade volumes between the economies. The exchange rate variable shows a positive and significant coefficient, suggesting that an appreciation of the exchange rate positively influences bilateral ICT trade. In simpler terms, when the local currency strengthens against the Indian Rupee, imported ICT goods become relatively cheaper. This situation can potentially stimulate increased demand for imported ICT goods, contributing to the positive impact on bilateral trade.

An intriguing issue that emerges is why the preference for India in Africa's ICT goods trade, despite being duty-free, was short-lived and eventually shifted towards China. One of the central factors could be the pricing of the products. China's reputation for large-scale production allows for a lower cost of production, making its goods more cost-effective. Some studies suggest that the lower cost might reflect lower quality. However, from a consumer's perspective, a lower-priced product is highly attractive, even if that means the quality is not top-tier (Githaiga, 2021). This trade-off between cost and quality might significantly influence African countries' pivot towards China.

Additionally, China implemented duty-free preferential policies for the least developed countries around the same time as India, which erased any cost advantage that African countries might have gained exclusively through trade with India (UNCTAD, 2016). Moreover, China has recently increased its engagement and investment in Africa, enhancing its bilateral ties across various sectors (Tsikata et al., 2008). This cements China's presence in the African markets and potentially offers more attractive terms of trade and collaboration, thus strengthening its economic and political relationships within the continent.

In conclusion, the research shows the untapped potential for ICT trade between India and the AU. It provides a comprehensive understanding of the factors influencing this trade, offering valuable insights for policymakers, trade facilitators, and businesses aiming to capitalise on this potential. Strengthening trade relations can boost both parties' economic prospects and play a pivotal role in Africa's digital transformation journey.

Given the evolving dynamics of India-Africa trade, especially with Africa's increasing digitalisation and India's competitive edge in ICT, the findings advocate for strategic policy interventions. These include the need for India to diversify its export destinations and the African market and to leverage policy instruments such as the Duty-Free Tariff Preference (DFTP) Scheme to bolster trade. The analysis also suggests enhancing digital infrastructure and regulatory frameworks to facilitate smoother trade flows, addressing 'behind-the-border' constraints, and fostering a digital ecosystem conducive to the growth of ICT goods trade. This strategic focus aims to amplify India's role in the global ICT market and supports Africa's digital transformation journey, indicating a mutually beneficial pathway for economic cooperation and development.

References

Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21-37. https://doi.org/10.1016/0304-4076(77)90052-5

Armstrong, S. P. (2007). Measuring trade and trade potential: A survey. *Crawford School Asia Pacific Economic Paper*, (368). http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1760426

Atif, R. M., Haiyun, L., & Mahmood, H. (2017). Pakistan's agricultural exports, determinants and its potential: an application of stochastic frontier gravity model. *The Journal of International Trade & Economic Development*, *26*(3), 257-276. https://doi.org/10.1080/09638199.2016.1243724

Bach, D. C. (2013). Africa in international relations: The frontier as concept and metaphor. *South African Journal of International Affairs*, *20*(1), 1-22. http://dx.doi.org/10.1080/10220461.2013.783283

Baier, S.L., & J.H. Bergstrand. (2009). Bonus vetus OLS: A simple method for approximating international trade cost effects using the gravity equation. *Journal of International Economics, 77*(1), 77–85. https://doi.org/10.1016/j.jinteco.2008.10.004

Balassa, B**.** (1965). Trade liberalisation and "revealed" comparative advantage. *The Manchester School*, 33(2), 99-123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x

Bankole, F. O., Brown, I., & Osei-Bryson, K. M. (2010). *Does investments in ICT impact Trade in Africa? A trend analysis of trade flows in Africa.* Annual Workshop of the AIS Special Interest Group for ICT in Global Development. http://aisel.aisnet.org/globdev2010

Bergstrand, J. H. (1985). The gravity equation in international trade: some microeconomic foundations and empirical evidence. *The Review of Economics and Statistics, 67*(3), 474–481. http://dx.doi.org/10.2307/1925976

Calandro, E., Gillwald, A., Moyo, M., & Stork, C. (2010). *Comparative ICT sector performance review 2009/2010* (Towards evidence-based ICT policy and regulation). Research ICT Africa. https://researchictafrica.net/publication/comparative-ict-sector-performance-review-20092010/

CEPII. (2022). *International trade gravity dataset*. http://www.cepii.fr/CEPII/en/cepii/cepii.asp

Chan, S. (2020). China’s evolving role in regional production networks: evidence from the ICT industry. *Journal of Southeast Asian Economies*, *37*(1), 78–92. https://www.jstor.org/stable/26938862

Chivunga, M., & Tempest, A. (2021). *Digital disruption in Africa: Mapping innovations for the AfCFTA in post-COVID times*. South African Institute of International Affairs. http://www.jstor.org/stable/resrep28288

Devadason, E. S., & Chandran, V. G. R. (2019). Unlocking the trade potential in China-ASEAN relations: The China-Vietnam context. *Journal of Southeast Asian Economies*, *36*(3), 380–399. https://www.jstor.org/stable/26842381

Drysdale, P., Huang, Y., & Kalirajan, K. (2000). China’s trade efficiency: Measurement and determinants. In P. Drysdale, Y. Zhang & L. Song (Eds.). *APEC and Liberalization of the Chinese economy*. Canberra: Asia Pacific Press (pp. 259–271).

Gakhar, S., and Gokarn, S., (2015). *India-Africa Trade And Investment: A Backdrop*. Brookings.

Githaiga, N. M. (2021). Kenya-China trade in manufactured goods: A competitive or complementary relationship?. *Open Journal of Social Sciences, 9*(3), 96-117. https://doi.org/10.4236/jss.2021.93007

Hassan, M. T. (2017). An analysis of prime determinants and constraints of Bangladesh’s export market: Stochastic frontier gravity model approach. *World Customs Journal*, *11*(2), 77-92. https://www.semanticscholar.org/paper/An-analysis-of-prime-determinants-and-constraints-Hassan/74d162fed61a01c13788ea36351f271925cf11a3

ICEA (2018). *Making India the global manufacturing powerhouse for mobile handsets and components*. India Cellular and Electronics Association.

International Monetary Fund. (2024). *GDP, current prices*. https://www.imf.org/external/datamapper/NGDPD@WEO/OEMDC/ADVEC/WEOWORLD

Kalirajan, K. (2007). Regional cooperation and bilateral trade flows: An empirical measurement of resistance, *The International Trade Journal, 21*(2), 85–107. https://doi.org/10.1080/08853900701266555

Kalirajan, K., & Findlay, C. (2005). Estimating potential trade using gravity models: A suggested methodology. *Foundation for Advanced Studies on International Development, Tokyo*.

Lunogelo, H. B., & Baregu, S. (2013). *Indo-Africa relationship: Opportunities for technology transfer between India and African countries*. Economic and Social Research Foundation (ESRF).

Manuwa, T. (2023). The digital transformation of diplomacy: Implications for the African Union. *East African Scholars Journal of Education, Humanities and Literature*, *6*(8), 365-372. http://dx.doi.org/10.36349/easjehl.2023.v06i08.002

Meeusen, W., & van Den Broeck, J. (1977). Technical efficiency and dimension of the firm: Some results on the use of frontier production functions. *Empirical Economics*, *2*, 109-122. https://doi.org/10.1007/BF01767476

Mikic, M., & Gilbert, J. (2007). *Trade Statistics in Policymaking: A Handbook of Commonly Used Trade Indices And Indicators*. United Nations.

Mishra, A. (2018). *The African Continental Free Trade Area and its Implications for India-Africa Trade.* Washington International Trade Association.

Montague-Mfuni, M., Fabian, F., & Scheepers, C. B. (2023). Advancing technological hub collaborations to promote transnational African communities. *Technological Leapfrogging and Innovation in Africa: Digital Transformation and Opportunity for the Next Growth Continent*, 71-88. https://doi.org/10.4337/9781800370395.00012

Nguyen, S. T., & Wu, Y. (2020). Governance and export performance in Vietnam. *Journal of Southeast Asian Economies*, *37*(1), 1–25. https://www.jstor.org/stable/26938858

Olper, A., & Raimondi, V. (2008). Explaining national border effects in the QUAD food trade. *Journal of Agricultural Economics* 59 (3): 436–462. https://doi.org/10.1111/j.1477-9552.2008.00155.x

Rajan, K. S. S. (1966). Tariff preferences and developing countries, *Finance & Development*, *0003*(004). https://doi.org/10.5089/9781616352844.022.A004

Sevela, M. (2002). Gravity-type model of czech agricultural export. *Agricultural Economics 48*(10) 463– 466. http://dx.doi.org/10.17221/5353-AGRICECON

Thahara, A. F., Rinosha, K. F., & Shifaniya, A. J. F. (2021). The relationship between exchange rate and trade balance: Empirical evidence from Sri Lanka. *Journal of Asian Finance, Economics and Business. 8*(5), 0037–0041. http://dx.doi.org/10.13106/jafeb.2021.vol8.no5.0037

The World Bank, World Development Indicators. (2022). *Population ages 0-14 (% of total population)* [Data file]. https://data.worldbank.org/indicator/SP.POP.0014.TO.ZS

Tsikata, D., Fenny, A. P., & Aryeetey, E. (2008). *China-Africa relations: A case study of Ghana*. AERC Scoping Studies on China-Africa Economic Relations.

UNCTAD. (2016). *Handbook on the Special and Preferential Tariff Scheme of China for Least Developed Countries*. United Nations. https://unctad.org/system/files/official-document/itcdtsbmisc76_en.pdf

UNCTAD. (2017). *Handbook on India's Duty-Free Tariff Preference Scheme for Least Developed Countries.* United Nations. https://unctad.org/system/files/official-document/itcdtsbmisc77_en.pdf

UNCTAD. (2018). *Updating the Partnership Definition of ICT Goods from HS 2012 to HS*

2017. United Nations. https://unctad.org/system/files/official-document/tn_unctad_ict4d02_en.pdf

UNCTADSTAT. (2023). *Bilateral Trade Flows by ICT Goods Categories, Annual* [Data file]. https://unctadstat.unctad.org/datacentre/dataviewer/US.IctGoodsValue

Conflict of Interest

The authors have no conflicts of interest to declare. The first author has seen and agrees with the contents of the manuscript, and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Ethical Approval

This manuscript, focusing on secondary data analysis related to international trade, was prepared with strict adherence to ethical guidelines relevant to the use of secondary data. Although our research did not directly involve human participants, all data utilised in this study were collected and processed in a manner that respects the principles outlined in the 1964 Declaration of Helsinki and its later amendments, or comparable ethical standards, ensuring data integrity, confidentiality, and respect for privacy. We confirm that all secondary data sources were accessed and used in compliance with applicable laws and regulations regarding data protection and intellectual property rights.

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Author Contribution Statement

The First Author (Corresponding Author): Conceptualisation; collecting resources; developing the first draft incorporating new ideas and relevant resources; grammar and language checking, proofreading, and finalising.

The Second Author**:** Conceptualisation; collecting resources; initial reviewing and cross-checking for references, final reviewing of the draft.

Both authors have read and agreed to the final version of the manuscript. Each author has participated sufficiently in the work to take public responsibility for appropriate portions of the content.

Data Availability Statement

The data supporting the findings of this study are derived from publicly available secondary sources. Specifically, the datasets utilised in our research were obtained from the United Nations Conference on Trade and Development (UNCTAD) database (UNCTADSTAT) and the World Bank database. These datasets are accessible online to any interested parties.

- The data from UNCTADSTAT can be accessed through the following link: https://unctadstat.unctad.org/datacentre/
- The World Bank data can be found at the World Bank's official data repository: https://data.worldbank.org/

These resources provide comprehensive data on international trade, which have been used under their terms of use. No additional permissions were required to access these datasets. Readers are encouraged to consult these sources directly to analyse and interpret the data in the context of this study or for their research purposes.

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Furthermore, we acknowledge the use of data from UNCTADSTAT and the World Bank database, which were instrumental in our research. Their open-access resources have enabled us to conduct a comprehensive analysis

and contribute to the academic discourse on international trade.

Appendix

Appendix 1: ICT Goods Categories and Composition (HS 2017)		
Label	**HS Codes**	**Number of items**
Computers and Peripheral Equipment (ICT01)	844331, 844332, 847050, 847130, 847141, 847149, 847150, 847160, 847170, 847180, 847190, 847290, 847330, 847340, 847350, 852842, 852852	17
Communication Equipment (ICT02)	851711, 851712, 851718, 851761, 851762, 851769, 851770, 852550, 852560, 853110	10
Consumer Electronic Equipment (ICT03)	851810, 851821, 851822, 851829, 851830, 851840, 851850, 851890, 851920, 851930, 851950, 851981, 851989, 852110, 852190, 852210, 852290, 852580, 852712, 852713, 852719, 852721, 852729, 852791, 852792, 852799, 852849, 852859, 852862, 852869, 852871, 852872, 852873, 950450	34
Electronic Components (ICT04)	852321, 852352, 853400, 854011, 854012, 854020, 854040, 854060, 854071, 854079, 854081, 854089, 854091, 854099, 854110, 854121, 854129, 854130, 854140, 854150, 854160, 854190, 854231, 854232, 854233, 854239, 854290	27
Miscellaneous (ICT05)	852351, 852359, 852380, 852910, 852990, 901320	6
Source: UNCTAD Database, 2023		