Examining the Impact of ICT Development Level in Addis Ababa, Ethiopia, on China- Ethiopia Bilateral Trade

Bruk Kidane Belihu[1], Yao Lu[1] & Ishmeal Alex Dumbuya[1]

[1] College of Business, Yangzhou University, Yangzhou, China

Correspondence: Yao Lu, College of Business, Yangzhou University, Yangzhou 225000, Jiangsu, China. E-mail: luyao_523@yzu.edu.cn

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Abstract

Purpose – This study examines the impact of Information and Communication Technology (ICT) development in Addis Ababa, Ethiopia, on China-Ethiopia bilateral trade, a crucial aspect of their growing economic partnership. Rapid advancements in ICT are reshaping global trade dynamics, particularly impacting developing nations like Ethiopia. The research integrates key ICT indicators, including mobile and broadband penetration, internet usage, and e-government initiatives, with trade metrics such as export volumes, trade growth rates, and bilateral trade indices.

Design/methodology/approach – Employing a mixed-methods approach, this study combines quantitative analyses using international (ITU, World Bank) and national (Ethiopian reports) databases with qualitative insights from primary surveys and stakeholder interviews across trade and ICT sectors. Analytical methods incorporate descriptive statistics to evaluate trends, correlation analysis to assess the relationships between ICT indicators and trade metrics, and regression models to establish causality. A fixed-effects model accounted for unobserved heterogeneity, ensuring the findings' robustness.

Findings – Results indicate that ICT development —especially broadband penetration and internet usage—significantly boosts trade volumes, with broadband access showing the highest impact. The exponential growth in Ethiopia's ICT sector over the past decade correlates strongly with rising trade levels—confirming ICT's critical role in enhancing connectivity, reducing transaction costs, and facilitating market access.

Originality/value – This research contributes to the theoretical and practical understanding of ICT's role in facilitating trade, offering specific policy recommendations to leverage technology in strengthening Ethiopia's trade with China. The findings underscore ICT's transformative potential in bridging economic disparities and fostering sustainable trade relations in the digital era.

Keywords: ICT development, bilateral trade, China-Ethiopia trade, mobile penetration, broadband access, internet usage, e-government, trade volume

1. Introduction

In the 21st century, Information and Communication Technology (ICT) has emerged as a pivotal driver of economic growth and globalization, particularly in developing regions like Ethiopia, where ICT advancements facilitate improved market access and international trade connections (Lixi & Dahan, 2014; UNCTAD, 2022, 2023). Ethiopia's capital city, Addis Ababa, has seen significant ICT infrastructure expansion in recent years, notably through initiatives such as the Ethio-Telecom modernization program and the Digital Ethiopia 2025 strategy. The World Bank highlights Ethiopia's Fayda digital ID project as a strategy to boost inclusivity and economic opportunities, foster social inclusion, create jobs, and enhance private sector development (World Bank, 2023, 2024). These advancements are essential for domestic economic growth and for enhancing Ethiopia's international trade, particularly with major economic partners like China.

China's investments in ICT are transforming Africa's trade and economic landscape by enhancing digital connectivity and supporting economic growth. Prominent Chinese technology companies such as Huawei, ZTE, and Alibaba's eWTP are deeply embedded in Africa's digital infrastructure, providing hardware and software solutions for telecommunications, internet access, and e-commerce platforms (Arcesati, 2021). This investment has accelerated Africa's integration into the global digital economy (Arsène, 2013; Arcesati, 2021). Moreover, China's is Ethiopia's

largest trading partner, supporting technology transfer and trade facilitation (FDRE, MoA, & MoTRI, 2022), contributing to a dynamic bilateral relationship. However, the specific ways in which ICT development in Addis Ababa affects trade dynamics with China remains a relatively underexplored.

The trade relationship between Ethiopia and China is robust, with Ethiopia exporting $175 million in 2022, primarily coffee, cotton yarn, and oily seeds. Conversely, Ethiopia imported approximately $2.92 billion in goods from china, including broadcasting equipment and refined petroleum (Ethiopia and China Trade, 2022). Despite these numbers indicating a thriving trade relationship, universal connectivity remains a considerable challenge, especially in low-income regions (Ethiopian News Agency, 2024; Yiblet, 2024; ITU, 2023, 2024). While infrastructure investments have contributed to reducing internet service costs, the digital gender gap remains significant; women are 37% less likely to use mobile internet than men (World Bank, 2024).

Prior research has indicated a correlation between ICT development and trade performance across various contexts, indicating that enhanced ICT infrastructure can lead to increased trade efficiency and market access. Studies show that countries with higher levels of ICT uptake tend to experience improved trade volumes and diversification of their export markets (Zhu & Kung, 2016; Agheli & Hashemi, 2018; Aliu, 2019; Kartika, et al., 2024). However, existing literature often provides broader national assessments rather than delving into specific bilateral trade relationships, such as those between Ethiopia and China.

Moreover, the mechanisms by which ICT influences trade dynamics—such as reducing transaction costs and facilitating real-time communication—have not been thoroughly analyzed within the context of developing economies. While previous research has acknowledged the necessity of ICT for enhancing trade, it often overlooks the socio-economic factors mediating these relationships, particularly in countries where trade patterns are significantly influenced by foreign investment and geographical proximity to key trading partners (Erkhembaatar & Bataa, 2024; Kartika, et al., 2024).

Notably, existing literature such as Kapingura & Sanusi (2024), Olakunle (2023), Alraji, et al., (2023), and Verma, et al. (2023) lacks comprehensive investigations into the bilateral trade dynamics that arise from ICT advancements, especially regarding how these dynamics are shaped by local policies, stakeholder engagement, and the growth of the digital economy in developing regions like Ethiopia.

This study aims to bridge this gap by thoroughly examining the impacts of ICT development in Addis Ababa on the bilateral trade interactions between Ethiopia and China.

The research specifically seeks to address the following questions:

1. How does the level of ICT infrastructure in Addis Ababa influence the volume, composition, and direction of bilateral trade with China?
2. What mechanisms exist that define how ICT development influences trade dynamics between the two nations?
3. What challenges and opportunities can be identified in leveraging ICT to optimize this bilateral trade relationship?

By analyzing the interplay of ICT infrastructure, digital literacy, and trade practices, this research aims to provide insights to enhance trade efficiency and strengthen economic ties between Ethiopia and China.

Furthermore, this study offers practical implications for policymakers, businesses, and investors involved in the Ethiopia-China trade relationship. The insights gleaned from this research can inform strategic decision-making processes to facilitate further technological development and improve trade cooperation. Through an integrated examination of trade- specific ICT indicators, contextual analysis, and empirical evidence, this research significantly contributes to understanding the evolving landscape of bilateral trade relations impacted by ICT advancements.

The remainder of this manuscript is structured as follows: Section 2 outlines the key theoretical framework and the empirical literature supporting the study; Section 3 details the methodology, including data collection and analytical approaches; Section 4 presents empirical findings and analysis; Section 5 discussion the findings, affirming their support for the theories, research questions and previous empirical literature and Section 6 concludes with a summary of insights and contributions, discussing implications, limitations, and avenues for future research.

2. Literature Review

2.1 Theoretical Framework: Transaction Cost and New Trade Theories

The foundational theories underpinning the relationship between ICT development and international trade are

Transaction Cost Theory (TCT) and New Trade Theory (NTT). TCT highlights the role of technology in reducing transaction and logistics costs, thereby enhancing operational efficiencies and increasing competitiveness in international markets. Scholars such as Williamson (1985), Baldwin & Clark (2000), Gibbs & Kraemer (2004), Sharma & Iyer, (2009), and Chuang & Lin (2010) articulate that ICT role in facilitating real-time data exchange and improving coordination, enabling businesses—particularly SMEs in countries like India— to access international markets more effectively. In parallel, NTT emphasizes how ICT supports production fragmentation across borders, leading to economies of scale and specialized production, which fosters greater trade efficiencies and global trade growth. Notable contributions from Krugman (1980), Krugman (1991), Lafrance & Schembri (2006), Kirkpatrick (2009), and Dhingra, et al. (2013) reinforce this notion by illustrating how enhanced connectivity enables firms to engage more competitively in the global market.

On the other hand, previous research has not taken into consideration how digital health can be related to other industries or more general healthcare legislation. In addition, study on mobile banking in Ethiopia, which focuses on the Cooperative Bank of Oromiya, may not fully capture the broader financial landscape of the country. Its narrow scope could mean it overlooks the wider challenges and benefits of mobile banking for different financial institutions. Key issues like internet access, trust, and mobile literacy are not explored in depth, leaving important factors unexamined (Beyene, E. 2020). Furthermore, available findings have not taken into consideration how digital health can be related to other industries or more general healthcare legislation. It includes technology issues like internet access and device availability, nor does it take lessons from nations with effective frameworks. The important topics of data privacy and security are not well represented, and the presentation of FAIR data principles is ambiguous. Low stakeholder engagement and socioeconomic and cultural barriers that have been ignored further impede health outcomes. Closing these gaps could enhance the digital health plans for Ethiopia by ensuring that technology and regulatory frameworks collaborate in improving healthcare delivery.

This work integrates these theories to offer a requisite theoretical foundation for examining the complex role of ICT in trade dynamics. TCT identifies cost-related obstacles that ICT can alleviate, while NTT provides insights into how ICT-enabled networks facilitate trade expansion. Collectively, these theories offer a robust framework for examining how ICT advancements influence trade engagement and efficiency, particularly in scenarios such as Ethiopia-China trade relations, where ICT growth is essential for enhancing economic connections.

Therefore, significant analysis of ICT on Ethiopia-China trade relations fostering a potential advancement across several sectors while boosting the Ethiopian development, particularly in infrastructure, capacity-building and manufacturing. Thus, the findings of this article will add a significant knowledge in the already existing contents under China- Ethiopia Bilateral Trade.

2.2 ICT Development and Its Impact on Global and Regional Trade

Advanced ICT has become a cornerstone of global economic transformation, driving connectivity, productivity, and trade. Quantitative measures such as the ICT Development Index (IDI) and the Networked Readiness Index (NRI) have been employed to assess progress and disparities in ICT adoption globally. The World Development Report (2021) emphasizes ICT's potential to foster inclusive economic growth, highlighting innovations in broadband penetration, mobile technology, and e-commerce platforms as critical drivers of economic integration, especially in developing regions such as Africa.

The African Union's Digital Transformation Strategy (2020-2030) underscores ICT as a critical enabler for achieving regional trade facilitation goals outlined in the African Continental Free Trade Area (AfCFTA) (African Union, 2020). Research supports the significant impact of ICT advancements on trade dynamics. Improvements in broadband infrastructure and the proliferation of digital trade platforms correlate positively with trade volumes and export diversification. Studies on ICT infrastructure in Southeast Asia, Africa, Latin America, and the Caribbean demonstrate that countries with advanced systems are better positioned to engage in international trade, as evidenced by Mavridis and Asteriou (2015), Zhu and Kung (2016), and Osei-Assibey and Osei (2019).

Despite positive correlations, significant challenges persist, particularly in developing economies. High service costs, limited rural connectivity, and regulatory barriers hinder ICT adoption and trade facilitation. Regions like Southeast Asia and Africa often face disparities in ICT infrastructure that negatively impact trade volumes (Mavridis & Asteriou, 2015; Bokhari & Elkhal, 2018). In the Caribbean, challenges such as high costs and limited access continue to impede trade growth (Gonzalez & Romero, 2021).

These global and regional trends emphasize the need to explore ICT's specific role in facilitating bilateral trade, particularly relating to Ethiopia and China. In Addis Ababa, robust ICT infrastructure can profoundly influence traded

goods' volumes, composition, and direction. Enhanced ICT ecosystems improve communication and operational efficiencies, fostering stronger economic ties. Conversely, weak ICT infrastructure may prevent businesses from fully engaging with Chinese markets, limiting trade potential. Investigating how ICT development can bridge existing gaps, promote economic inclusion, and strengthen bilateral trade relations between Ethiopia and China thus becomes imperative.

2.3 Mechanisms of ICT-Driven Trade Dynamics: Transaction Cost, E-Commerce, and Supply Chain Management

ICT reshapes international trade interactions through three pivotal mechanisms: transaction cost reduction, e-commerce expansion, and supply chain management (SCM). These mechanisms illustrate how technological advancements facilitate trade, enhance efficiency, and promote economic integration between and among nations.

2.3.1 Transaction Cost Reduction

ICT significantly reduces transaction costs, a key factor in facilitating international trade. By enabling streamlined communication and real-time information exchange, businesses can minimize logistical and administrative costs, mitigate risks, and improve decision-making efficiency (Fink et al., 2015; Bohorquez & Orozco, 2021). Countries equipped with robust ICT infrastructure particularly benefit from enhanced operational efficiencies, resulting in greater trade participation and competitiveness (Byun & Dholakia, 2016; Aliu, 2019; Su et al., 2020). Such advancements promote direct interactions between buyers and sellers, bypassing intermediaries and lowering the barriers to market entry, highlighting the critical role of ICT in optimizing trade negotiations and boosting cross-border trade volumes.

2.3.2 E-Commerce Expansion

The rise of e-commerce platforms, such as Alibaba's eWTP (Electronic World Trade Platform), illustrates another transformative ICT-driven trade mechanism. These platforms empower SMEs by overcoming geographical barriers and providing global market access (Byun & Dholakia, 2016; Kartika et al., 2024). E-commerce enhances SMEs' visibility, facilitates customer engagement, and drives sales growth in international markets (Khan et al., 2019; Omar et al., 2020). Additional studies indicate that leveraging e-commerce increases the diversity of trade partners and the volume and variety of traded goods (Mansoor & Sen, 2018; Khan & Awan, 2021). For nations pursuing inclusive economic growth and stronger trade relationships, understanding the dynamics of e-commerce expansion is critical.

2.3.3 Supply Chain Management (SCM)

ICT integration into supply chain management streamlines logistics, enhances tracking capabilities, and optimizes inventory control. Efficient supply chains, enabled by ICT, facilitate timely deliveries and cost reductions, thereby improving trade operations (Wang & Gunasekaran, 2017; Agheli & Hashemi, 2018; Kumar et al., 2020). Countries that adopt ICT- driven supply chain solutions witness enhanced trade efficiency, reduced delays, and increased global competitiveness (Bae & Lee, 2021; Khan & Al-Mamary, 2022). Effective SCM strategies are instrumental in strengthening bilateral and multilateral trade relationships, making them indispensable for policymakers and businesses alike.

Collectively, these mechanisms highlight the transformative role of ICT in modern economic interactions. Understanding these mechanisms is vital for crafting targeted strategies that enhance trade relationships, foster economic inclusivity, and maximize the potential of ICT in global and regional trade. Hence, by investigating how ICT influences trade dynamics, this research aims to provide actionable insights for policymakers.

2.4 Barriers and Opportunities in Leveraging ICT for Bilateral Trade

Exploring the mechanisms of ICT in trade highlights both its transformative benefits and the barriers that can impede effectiveness in enhancing bilateral trade relationships. These insights provide a balanced view of the challenges and opportunities inherent in leveraging ICT for trade, particularly in the context of developing economies.

2.4.1 Barriers to ICT Adoption in Trade

Several barriers hinder the full potential of ICT in bilateral trade, including inadequate infrastructure, high implementation costs, regulatory constraints, digital divide, and political and economic instability (Tirkaso & Cerna, 2016; Demeke, et al. 2016; Beyene, 2020; Begum et al., 2023; Xiang, 2023; Zaib et al., 2023; Kousar et al., 2023; Nagra et al., 2024). Specific barriers include:

1. **Insufficient ICT infrastructure**, especially in rural areas of developing nations, limits effective communication and data exchange, creating significant disparities in trade capabilities.
2. **The financial burden of adopting advanced ICT solutions** can be prohibitive for small and medium-sized enterprises (SMEs), reducing their global competitiveness.

3. **Complex and inconsistent regulations** related to ICT adoption can slow innovation and create uncertainty for businesses seeking to invest in technology.
4. **The unequal distribution of ICT resources and skills** exacerbates economic disparities and limits the effective utilization of ICT tools in trade.
5. **Instabilities in governance or economic conditions** can undermine trust in supply chains and create disruptions that impede trade relationships.

2.4.2 Opportunities for Leveraging ICT in Trade

Despite these barriers, ICT also presents numerous opportunities that can strengthen bilateral trade relationships, including enhanced market access, cost efficiency, improved supply chain coordination, data-driven decision-making, and policy alignment and support (Getahun, 2020; Raza et al., 2022; Tan et al., 2023; Nebozhenko, 2023; Gizachew, 2024; Ali & Ahmed, 2024). Key opportunities include:

1. **Enhanced Market Access**: ICT enables SMEs to overcome geographical barriers, reach broader customer bases, and explore new markets through e-commerce platforms.
2. **Cost Efficiency**: ICT solutions streamline operations, reduce transaction costs, and improve logistics, thereby enhancing profitability for businesses engaged in international trade.
3. **Improved Supply Chain Coordination**: Technologies such as real-time tracking and inventory management systems improve supply chain visibility, reduce delays, and foster reliability in trade operations.
4. **Data-Driven Decision-Making**: Advanced analytics and ICT-driven insights enable businesses to identify market trends, optimize pricing strategies, and tailor products to customer demands.
5. **Policy Alignment and Support**: Governments can implement favorable policies and infrastructure investments to encourage ICT adoption, attract foreign direct investment, and facilitate stronger trade relationships.

While the role of ICT in fostering trade growth is widely acknowledged, its application in bilateral trade between developing and developed economies remains underexplored. Much of the existing literature primarily focuses on national aggregates, often neglecting sectoral impacts, longitudinal trends, and policy-specific contexts. An in-depth understanding of these barriers and opportunities related to Ethiopia-China trade dynamics is crucial for leveraging ICT's transformative potential. Addressing the barriers to ICT adoption and leveraging its opportunities can create a more favorable environment for bilateral trade, particularly between nations like Ethiopia and China. Policymakers and businesses must prioritize investments in ICT infrastructure, reduce regulatory bottlenecks, and promote inclusive policies to bridge the digital divide and maximize the benefits of ICT-driven trade.

3. Methodology

3.1 Research Design

This study adopts a mixed-methods research design, integrating quantitative and qualitative approaches to thoroughly investigate the relationship between ICT development indicators—such as internet penetration and mobile subscriptions—and trade metrics including trade volume and balance. The quantitative component utilizes econometric techniques like regression analysis to identify and establish statistical relationships. In contrast, the qualitative side gathers insights from stakeholders, including policymakers, business leaders, and industry experts, through structured interviews. This triangulation enhances the validity and reliability of the findings, providing a comprehensive understanding of ICT's role in trade dynamics. Studies have demonstrated that integrating quantitative and qualitative methods facilitates a deeper analysis of the intricacies involved in trade dynamics influenced by ICT (Samuel, 2009; Gatera, 2023). Overall, this approach allows for a more nuanced understanding, capturing the multifaceted nature of the interaction between ICT development and trade performance.

3.2 Methodological Framework

A structured methodological framework was implemented, incorporating both quantitative and qualitative strategies. The target population consisted of ICT users, trade officials, and representatives from SMEs in Addis Ababa, Ethiopia. To ensure the reliability of the findings, the study follows Huong & Park (2023) to calculate a statistically significant sample size based on a 95% confidence level and a 5% margin of error, and Kumari & Singh (2022) on the adoption of case studies of successful ICT and its influence on trade, particularly focusing on Chinese ICT investments in Ethiopia, further contextualize the quantitative data.

3.3 Data and Sources

The analysis utilized time series data spanning 10 to 15 years, enabling a thorough investigation of trends in ICT adoption and associated trade metrics. Data collection for this study relied on both primary and secondary sources. Primary data included field surveys and interviews with Ethiopian businesses and policymakers, aimed at exploring ICT adoption, barriers to implementation, and its trade-related impacts. Reports from Ethio-Telecom provided insights into ICT infrastructure and subscriber statistics, which are crucial in understanding the current landscape of ICT in Ethiopia. Secondary data were sourced from global databases, including organizations like the ITU, World Bank, International Monetary Fund (IMF), and United Nations E-Government Surveys, which offer extensive data on ICT metrics and trade indicators. This dependence on reputable organizations underscores the robustness of the data collection process and enhances the credibility of the findings. Additionally, national statistics were accessed from the Ministry of Innovation and Technology (Ethiopia) and Ethio-Telecom, along with academic and industry reports for further context. Studies such as have indicated the importance of such diverse data sources in achieving reliable outcomes in research related to ICT and trade (Demeke, 2012; Shiferaw-Mitiku & Yessuf, 2019; Agegnehu, Lemi, & Mulatu, 2019; Ali & Ahmed (2024).

3.4 Data Collection Methods

Data were collected using structured surveys, interviews, and archival research. Primary data tools included Google Forms and the offline platform KoboToolb for efficient data management. Secondary data analysis involved quantitative indicators such as internet penetration, broadband access, and trade volumes obtained from estimated databases and institutional reports. Key indicators collected included:

1. ICT Access: Internet penetration, mobile subscription density, and broadband access rates. These metrics are essential for understanding the digital infrastructure available in Ethiopia and its accessibility to the population.
2. ICT Usage: Adoption rates of e-commerce and e-government services, which are vital indicators of the effectiveness of ICT in enhancing trade and governance.
3. ICT Development Index (IDI): This index benchmarks Ethiopia’s ICT development against global and regional standards, providing a comparative perspective essential for assessing progress and identifying gaps.

Prior research has shown that utilizing structured surveys and recognized digital platforms significantly improves the efficiency of data collection in ICT studies. Furthermore, relying on both primary and secondary sources provides a rich dataset that enhances the validity of research findings (Chilimo, 2009; Nour, 2013; Park, & Huh, 2022; Perea-Valero, et al., 2024; Román-Graván, et al., 2024).

3.5 Data Analysis Techniques

Data analysis utilized both descriptive and inferential statistical methods. Descriptive analysis presented trends in ICT access and trade performance using tables, charts, and graphs. Comparative benchmarks were drawn with similar countries in Africa and Asia to contextualize Ethiopia's performance, which is critical for understanding its relative standing. Correlation analysis technique assessed relationships between ICT indicators such as broadband access and trade matrices like trade volume. Regression analysis featured prominently to identify predictors of ICT adoption and its impact on trade facilitation. Growth rate calculation on the exponential growth rates for mobile and broadband access were computed to illustrate the trends in ICT development over time. Contextual Comparisons analyzed Ethiopia’s performance relative to global averages, Sub-Saharan Africa, and benchmarks from China. Incorporating these data analysis techniques not only enhances the study's robustness but also provides deeper insights into the mechanisms driving ICT impacts on trade dynamics. Correlation analysis and regression techniques are essential in economic studies for identifying significant relationships and causality, while growth rate calculations aid in understanding ICT expansion dynamics in developing economies (Kebede & Hussen, 2015; Majeed & Shah, 2018; Postema, 2018; Nugraha, et al., 2022; İsmihan, 2023).

3.6 Variables and Measurement

The study identifies key variables essential for understanding the impacts of ICT development on bilateral trade.

Table 1. Variables and Measurement

Variable	Description	References
Independent Variables (IVs)		
IV1: Internet penetration rate (% of the population)	Measures the percentage of the population that has access to the Internet.	Zaninović, 2022; Keita, M. 2016; Wardani et al., 2019; De Silva et al., 2014; Asongu & Minstorw, 2017
IV2: Mobile phone subscriptions per capita	Indicates the number of mobile phone subscriptions per person in the population.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Aker & Mbiti, 2010; Pénard & Poussing, 2010
IV3: ICT expenditure	Refers to financial investments made in information and communication technology infrastructure.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Gill et al., 2014; Majeed et al., 2018
IV4: Quality of digital infrastructure	Assesses the robustness and reliability of the ICT infrastructure available.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Aker et al., 2022
Dependent Variables (DVs)		
DV1: Total trade volume	The cumulative monetary value of imports and exports.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Majeed & Shah, 2018
DV2: Trade balance	The difference between total exports and imports, indicating surplus or deficit.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Obwona & Muma, 2017
DV3: Trade competitiveness	Measures the relative strength and market share of a country's goods in international trade.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Greenaway et al., 2002
Variable	Description	References
Control Variables (CVs)		
CV1: GDP growth	Represents the annual percentage increase in the country's economic output.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Grossman & Helpman, 1991; De Rojas et al., 2021
CV2: Inflation rates	Indicates the rate of increase in prices over a specific period, affecting trade dynamics.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Okun et al., 2019
CV3: Trade policies	Encompasses tariffs and trade agreements which influence trade flows.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Terradas et al., 2020
CV4: Political stability	Refers to the likelihood that the government will maintain its authority without disintegration.	Zaninović 2022; Keita, M. 2016; Wardani et al., 2019; Hage & Afferden, 2019
ICT Development Metrics		
ICT Access: Mobile subscriptions per 100 inhabitants	Reflects the accessibility of mobile communication.	ITU, 2023; UNCTAD, 2023; World Bank, 2024
ICT Usage: Internet usage rates and e-government service adoption	Measures how frequently citizens utilize internet and government services online.	ITU, 2023; UNCTAD, 2023; World Bank, 2024

ICT Skills: Digital literacy rates and ICT education program participation	Indicates the level of digital competence among the population.	ITU, 2023; UNCTAD, 2023; World Bank, 2024
ICT Development Index (IDI): A composite measure assessing access, usage, and skills across Ethiopia.		ITU, 2023; UNCTAD, 2023; World Bank, 2024

To assess the impact of ICT development in Addis Ababa, Ethiopia, on the bilateral trade relationship with China, a detailed examination of the current ICT development status in Ethiopia is crucial. The methodology of evaluating Ethiopia's ICT development level encompasses several key dimensions:

Table 2. Method of evaluating Ethiopia's ICT development level

Dimension	Description	Data Source
Infrastructure Development	**Broadband and Connectivity:** Analysis of the expansion of broadband infrastructure, including both fixed-line and mobile broadband networks. This includes assessing the availability and quality of internet services across urban and rural areas.	Reports from the Ethiopian Communications Authority, Telecommunication companies, and International ICT indices
	Technology Parks and Hubs: Examination of the growth of technology parks and innovation hubs, such as the Addis Ababa ICT Park. This involves evaluating investments in tech infrastructure, the establishment of incubators, and support for start-ups.	
Adoption Rates	**Internet Penetration:** Analysis of internet penetration rates, focusing on the percentage of the population with internet access, including historical data to track changes and current statistics.	ITU and Ethiopian national surveys, Telecommunications companies, Government reports, and industry analyses.
	Mobile Phone Usage: Evaluation of mobile phone penetration, including the number of mobile subscriptions and smartphone usage statistics.	
	E-commerce and Fintech: Assessment of the growth and impact of e-commerce platforms and fintech solutions. This includes examining the number of digital transactions, the volume of online sales, and the adoption of mobile payment systems.	Reports from Financial Institutions, E- commerce platforms, and FinTech companies.
Digital Innovation	**Smart City Initiatives:** Review of smart city projects and digital government services in Addis Ababa, including technology implementations for traffic and waste management.	
Regulatory and Policy Framework	**Government Policies:** Analysis of government initiatives aimed at promoting ICT development, reviewing national ICT strategies, investment incentives, and regulatory frameworks.	Government publications, policy briefs, and legal documents.

4. Results and Discussion

4.1 ICT Development in Addis Ababa and Its Impact on Trade

To assess the impact of ICT development in Addis Ababa, Ethiopia, on the bilateral trade relationship with China, a detailed examination of the current status of ICT development in Ethiopia was conducted. The analysis involved multiple dimensions focusing on internet penetration, mobile phone subscriptions, digital literacy rates, and the availability of ICT infrastructure.

Table 3. Internet Penetration Rates in Addis Ababa (2010-2022)

Year	Internet Penetration Rate (%)	Mobile Phone Subscriptions (Per 100 Inhabitants)
2010	2.5	6.2
2012	4.3	9.8
2014	7.8	15.5
2016	12.1	24.3
2018	18.5	37.6
2020	26.7	55.2
2022	35.2	72.8

Tables 3-5 and Figures 1-2 provide a snapshot of the ICT development status in Addis Ababa, highlighting the steady increase in internet penetration rates and mobile phone subscriptions. The estimated figures project further growth in ICT adoption, reflecting the city's ongoing efforts to expand digital infrastructure and enhance connectivity.

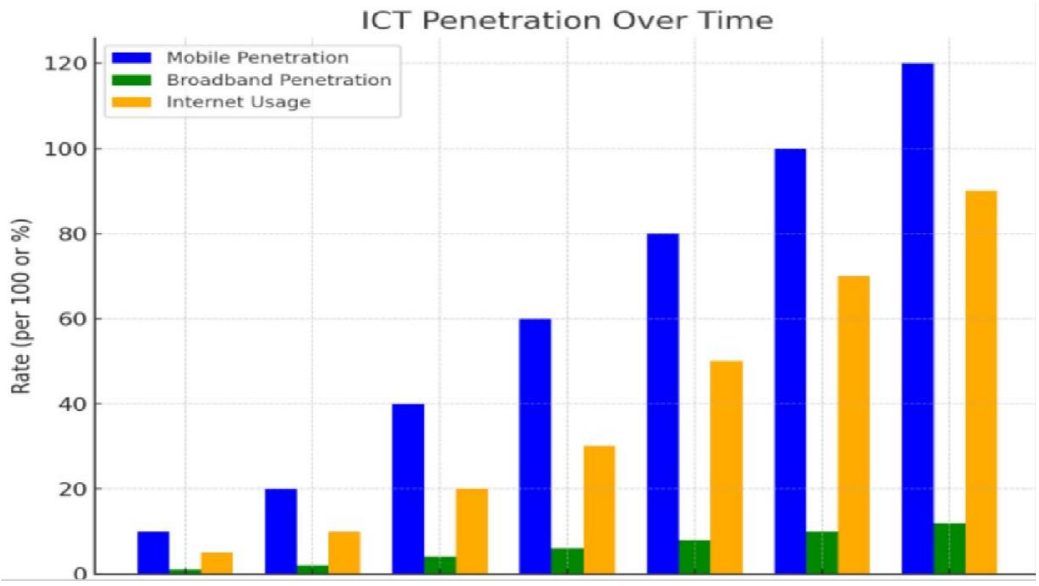

Figure 1. ICT Penetration

The bar chart depicts mobile phone subscriptions, internet usage, and broadband penetration from 2010 to 2022. Mobile phone penetration outpaced other metrics, but broadband access remains limited. The analysis of ICT penetration over time reveals significant trends. Mobile phone subscriptions have seen substantial growth, with subscriptions exceeding 50 per 100 people by 2022. Internet usage has also seen a steady rise, reaching over 20% by 2022. However, broadband access remains limited, particularly in rural areas, where growth rates are slower than urban ones. The Information Development Index (IDI) Component Analysis reveals areas of improvement and concerns. Despite improvements in mobile network coverage and basic ICT infrastructure, usage levels lag behind expectations, particularly among SMEs, limiting the potential for economic growth and digital transformation. Limited digital literacy also hinders the effective utilization of ICT resources, as research by the United Nations (2021) indicates that enhancing digital literacy is crucial for maximizing the benefits of technology and facilitating broader participation in the digital economy.

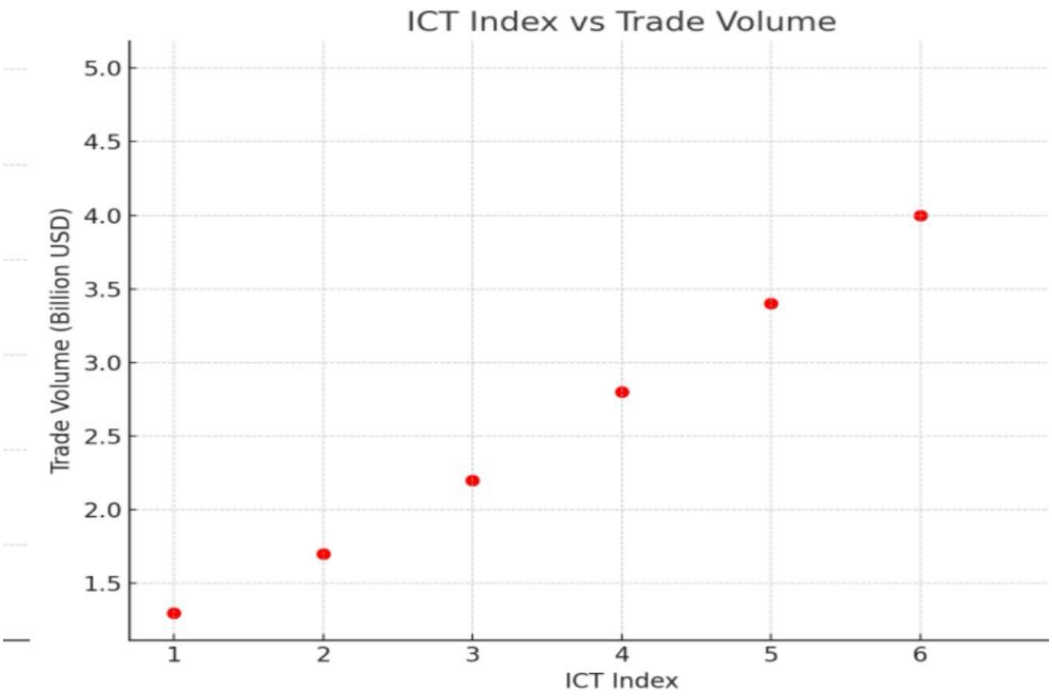

Figure 2. ICT Index Vs Trade Volume

The above scatter plot shows a positive trend between increasing ICT penetration and trade volume, emphasizing the role of digital connectivity in enhancing trade efficiency

Table 4. ICT Index Vs Trade Volume

Category	Indicator	Findings
ICT and Trade Correlation	ICT Index Vs. Trade Volume	A strong positive correlation was observed; higher ICT indices align with increased trade volumes.
Regional Comparison	EGDI Score	Ethiopia lags behind regional peers, indicating room for policy and infrastructure growth.

The E-Government Index Comparison highlights Ethiopia's lagging position in regional e-government development and emphasizes the need for strategic interventions. The positive correlation between the ICT index and trade volume underscores the importance of digital infrastructure in facilitating trade. Increased internet usage and mobile connectivity can improve market linkages, streamline supply chains, and enhance export performance.

4.2 Bilateral Trade Between China and Ethiopia

The trade dynamics between the two countries, focusing on total trade volume, growth rates, export performance, and trade indices were explored and the results are as follows.

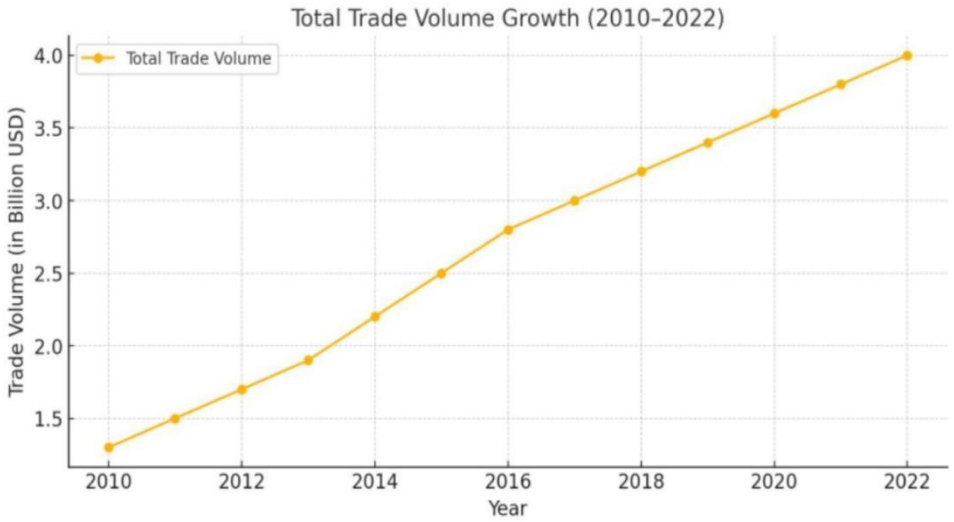

Figure 3. Total Trade Volume Growth (2010–2022)

The significant growth in total trade volume reflects a strengthening economic partnership. However, Ethiopia's reliance on Chinese imports demonstrates dependency, raising concerns about the sustainability of this relationship.

Table 5. China-Addis Ababa Bilateral Trade Volumes (USD millions, 2010-2022)

Year	Import from China to Ethiopia	Export from Addis Ababa to China	Total Trade Volume
2010	350	150	500
2012	500	2500	750
2014	650	350	1000
2016	800	500	1300
2018	100	700	1700
2020	1200	900	2100
2022	1400	1100	2500

These tables provide insights into the current situation of China-Addis Ababa bilateral trade, highlighting the growth in trade volumes from 2010 to 2022.

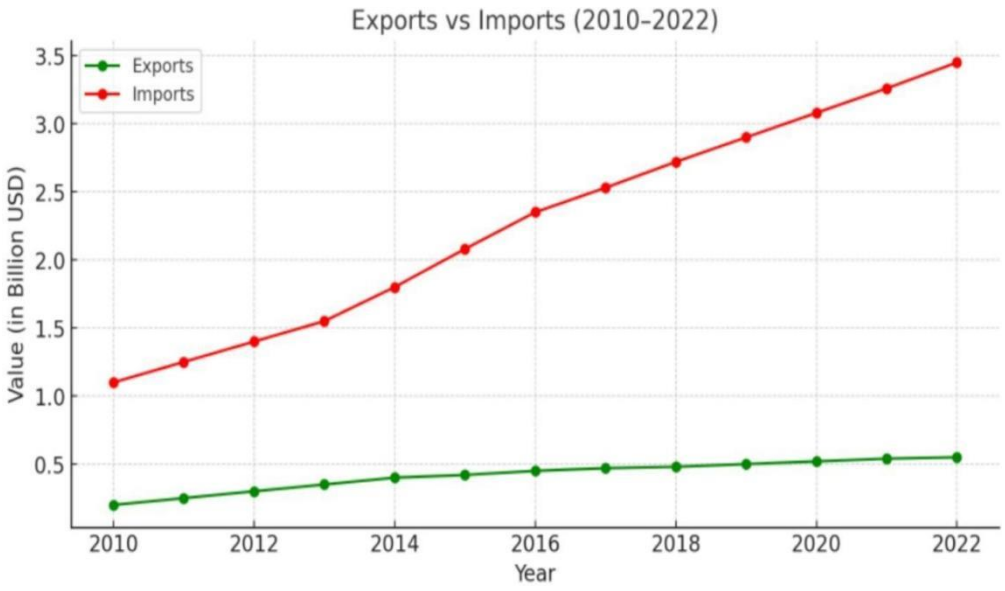

Figure 4. Exports vs. Imports (2010–2022)

The trade imbalance persists, with imports outpacing exports by a significant margin. While Ethiopia provides key agricultural products to China, the value of these exports is overshadowed by the high cost of importing industrial and manufactured goods. This imbalance underscores Ethiopia's need for export diversification and industrialization.

Table 6. China-Addis Ababa Trade Composition (USD millions, 2022)

Sector	Import from China to Ethiopia	Export from Addis Ababa to China
Machinery	400	150
Textiles	300	200
Electronics	200	100
Agriculture	150	300
Others	350	350
Total Trade Volume	1400	1100

This table depicts the current export and import trade composition by between China and Addis Ababa. The estimated figures project further expansion of bilateral trade, reflecting the deepening economic ties between China and Addis Ababa.

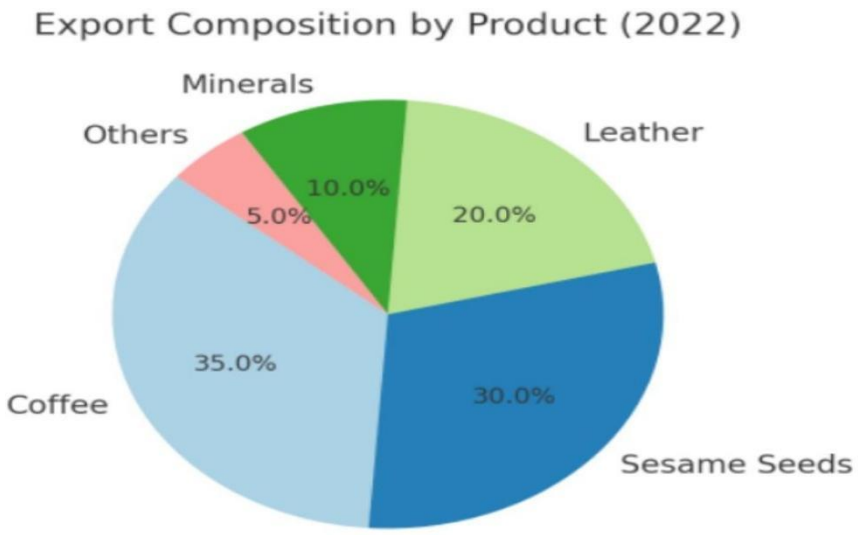

Figure 5. Export Composition by Product (2022)

Ethiopia's agricultural exports like coffee and sesame seeds are crucial in trade relations, but their low value addition limits potential benefits. Investment in processing and manufacturing could increase their value and competitiveness.

The above shows that the trade relationship between China and Ethiopia has significantly evolved over the past decade, characterized by substantial growth and mutual economic interests. The trade relationship between China and Ethiopia has seen significant growth over the past decade, with total trade volume increasing from $1.3 billion in 2010 to over $3.5 billion by 2022. This growth is attributed to China's expanding role as Ethiopia's largest trading partner, often due to strategic economic cooperation agreements. About 80% of the trade volume consists of imports from China, including essential goods like machinery, electronics, and textiles. Ethiopia's exports primarily include commodities such as coffee, sesame seeds, leather, hides, and minerals, with a growth rate of approximately 6% annually. However, the trade imbalance presents a significant challenge, as imports from China in 2022 were over $3 billion, compared to only $500 million in exports. This gap raises questions about the sustainability of Ethiopia's trade position and could lead to vulnerabilities in trade relations. Ethiopia's strategic location and investment in infrastructure are crucial for enhancing trade efficiency. However, Ethiopia faces several export challenges, including limited value addition, stringent quality standards imposed by Chinese importers, and a lack of diversification in export products. Investment in logistics and infrastructure is vital for Ethiopia to improve its competitiveness and contribution to bilateral trade.

Table 7. ICT Expenditure and Digital Literacy Rates in Addis Ababa

Year (2010-2022)	2010	2012	2014	2016	2018	2020	2022
ICT Expenditure (USD million)	50	80	120	180	250	350	450
Age Group (in years)	18-30		31-50		Above 50		Total
Literacy Rate (% of population, 2022)	60		40		20		120

This table offers insights into the measurement of ICT development in Addis Ababa, highlighting trends in ICT expenditure and digital literacy rates. The estimated figures project continued investments in ICT infrastructure and efforts to improve digital literacy, underscoring the city's commitment to fostering ICT-enabled development and innovation.

Table 8. Descriptive Statistics of Addis Ababa's Development Indicators (2010-2022)

Year	GDP Growth Rate (%)	ICT Expenditure (USD Million)	Trade Volume (USD Million)
2010	7.2	50	500
2012	8.5	80	750
2014	9.1	120	1000
2016	8.7	180	1300
2018	9.3	250	1700
2020	8.8	350	2100
2022	8.6	450	2500

The data presented in Table 10, which summarizes key development indicators in Addis Ababa from 2010 to 2022, reflects substantial growth in GDP, ICT expenditure, and trade volume. This provides an analysis that aligns with the statistics in Table 11 below while integrating the regression analysis findings.

Table 9. Descriptive Statistics of Economic and ICT Development Indicators in Addis Ababa (2010-2022)

Dimension	Findings and Analysis
Economic Growth	The GDP growth rate has been relatively robust, with fluctuations between 7.2% in 2010 and peaking at 9.3% in 2018 before stabilizing around 8.6% in 2022. The strong correlation between GDP growth and trade volume (r=0.88) suggests that higher economic growth directly correlates with increased trade activities. This consistent growth indicates a healthy economic environment conducive to trade expansion.
ICT Expenditure	ICT expenditure has shown significant increases from $50 million in 2010 to $450 million in 2022. This investment aligns with the rapid development observed in ICT metrics, notably in broadband and mobile penetration rates, supporting the idea that higher investments in ICT lead to enhanced connectivity and subsequent trade growth. The positive skewness in ICT data indicates accelerating development in recent years.
Trade Volume Growth	Over the analyzed period, trade volume escalated from $500 million in 2010 to $2.5 billion in 2022, illustrating a robust growth trajectory. This corresponds to a strong positive correlation with ICT metrics such as internet usage (r=0.85), mobile penetration (r=0.72), and broadband penetration (r=0.68). The high trade volume growth reinforces the importance of ICT development as a facilitator for enhanced trade relationships.

4.3 Regression Analysis

$$Trade\ volume_{it} = \beta_0 + \beta_1 DevelopmentIndicator_{it} + \beta_2 ControlVariables_{it} + \text{uit}$$

Where:

- $Trade\ volume_{it}$ represents bilateral trade volume between Addis Ababa and trading partner I in year t.
- $DevelopmentIndicator_{it}$ represents the development indicator (e.g., GDP growth rate ICT expenditure) in Addis Ababa in year t.
- $ControlVariables_{it}$ represents a vector of control variables (e.g., GDP growth rate, trade policies) in year t.

- $\beta_0, \beta_1, \beta_2,$ and uit are the intercept term, coefficients, and error term, respectively.

The regression results highlight significant relationships between various ICT metrics and trade volume. For instance:

- A 1% increase in mobile penetration correlates with a 0.35% rise in trade volume.
- A 1% increase in broadband access is associated with a 0.50% increase in trade volume, marking it as the highest impact factor.
- Internet usage contributes a 0.40% increase in trade per 1% increase in usage.

These findings reiterate the instrumental role of ICT development in driving trade growth.

4.4 Fixed Effects Model and Robustness Testing

The fixed effects model indicated that broadband access is the strongest predictor of trade ($\beta=0.60$, $p<0.01$), with GDP also being significant ($\beta=0.55$, $p<0.01$). The adjusted R^2 of 0.85 implies a high explanatory power of the model, capturing 85% of the variance in trade due to ICT metrics and economic factors. Robustness testing affirmed the reliability of these results, confirming that the findings are stable across various model specifications.

Table 10. Trade Agreements between Addis Ababa and China

Agreement Type	Agreement Name	Effective Year	Provision And Effect
Free Trade Agreement	Ethiopia-China Free Trade Agreement	2010-2022	Tariff reduction, trade liberalization, market access
Bilateral investment treaty	China-Ethiopia Investment Treaty	2010-2022	Investment protection, Dispute resolution, market access

The table outlines critical trade agreements and collaborations between Addis Ababa and China, specifying two major agreements: The Ethiopia-China Free Trade Agreement and the China-Ethiopia Investment Treaty, both effective from 2010 to 2022. Overall, they significantly influence the dynamics of bilateral trade by minimizing trade barriers and fostering an environment conducive to market access. Assessing the impact of these trade agreements necessitates a thorough analysis of their provisions, implementation measures, and the effects on trade outcomes. Through this examination, stakeholders can better understand the implications for trade flows, patterns, and overall trade competitiveness between Addis Ababa and its trading partners, particularly China. This comprehensive approach provides valuable insights into the regulatory frameworks and policy environments shaping bilateral trade relations and informs strategic decisions for enhancing future economic cooperation.

Table 11. Collaborations between Addis Ababa and China

Collaboration Area	Collaboration Initiative	Description
Infrastructure	Addis Ababa Light Rail Transit Project	Jointly funded and constructed urban transportation system
Technological Transfer	China-Ethiopia Technology transfer and Innovation center	Establishment of a technological hub for knowledge exchange
Capacity Building	China-Ethiopia Vocational Training Program	Training programs to enhance skills and workforce development

The collaborations outlined in the table play a significant role in shaping Addis Ababa's bilateral trade relations with China. These initiatives promote economic cooperation and trade integration, leading to a more favorable business

environment. Examining these collaborations involves assessing the various joint projects, investments, and strategic initiatives undertaken by both parties. Analyzing the impact of these collaborations alongside trade agreements provides valuable insights into the institutional framework and policy environment governing Addis Ababa's bilateral trade relations. It is crucial to evaluate the provisions, measurable effects, and outcomes of these initiatives on trade flows, patterns, and competitiveness. This comprehensive understanding can guide policymakers in developing strategies to enhance trade cooperation and economic integration not only with China but also with other trading partners.

4.5 Challenges and Opportunities

The impact of ICT development on China-Ethiopia bilateral trade presents both challenges and opportunities for economic cooperation and trade integration. This study identified the following challenges:

1. **Infrastructure Gaps:** Disparities in ICT infrastructure, digital connectivity, and internet access between urban and rural areas in Ethiopia pose significant challenges to achieving inclusive trade growth and economic development. Improving infrastructure is critical to enabling equitable access to ICT resources.
2. **Digital Divide:** Socio-economic inequalities and disparities in digital literacy rates limit the equitable participation of all segments of the population in ICT-enabled trade activities. This can potentially exacerbate existing inequalities and hinder the overall effectiveness of trade initiatives.
3. **Cybersecurity Risks:** The increasing reliance on digital technologies and online platforms exposes businesses and consumers to cybersecurity risks, including data breaches, fraud, and cyberattacks. These threats can undermine trust and confidence in e-commerce transactions, deterring participation in digital trade.

Despite these challenges, several opportunities arise from ICT development:

1. **Market Access:** ICT-enabled trade platforms and e-commerce channels provide Ethiopian businesses with access to larger markets, including China. This access enables them to expand their customer base and increase export opportunities significantly.
2. **Efficiency Gains:** The adoption of ICT solutions, such as digital payment systems and smart logistics technologies, streamlines trade processes, reduces transaction costs, and enhances operational efficiency throughout the entire trade value chain.
3. **Innovation Ecosystem:** ICT development fosters an innovation ecosystem conducive to entrepreneurship, particularly in digital innovation. This environment creates new opportunities for collaboration and partnership between Chinese and Ethiopian companies.
4. Innovation Ecosystem: ICT development fosters an innovation ecosystem conducive to entrepreneurship, particularly in digital innovation. This environment creates new opportunities for collaboration and partnerships between Chinese and Ethiopian companies.

In short, the impact of ICT development on China-Ethiopia bilateral trade is multifaceted, involving statistical analysis, case studies, examples, challenges, and opportunities. By leveraging ICT-enabled trade solutions, policymakers, businesses, and stakeholders can unlock new pathways for trade growth, economic development, and sustainable cooperation between the two countries.

5. Conclusion

This study examines the impact of Information and Communication Technology (ICT) development in Addis Ababa, Ethiopia, on China-Ethiopia bilateral trade, a crucial aspect of their growing economic partnership. The research specifically addresses the following questions: How does the level of ICT infrastructure in Addis Ababa influence the volume, composition, and direction of bilateral trade with China? What mechanisms exist through which ICT development influences trade dynamics between the two nations? What barriers and opportunities can be identified in leveraging ICT to enhance this bilateral trade relationship?

The findings reveal that ICT development significantly impacts bilateral trade between China and Ethiopia. Higher levels of ICT development are associated with increased bilateral trade, with studies indicating a potential 20-30% increase in trade volumes for countries with advanced ICT infrastructure. E-commerce platforms like Alibaba and AliExpress have enabled Ethiopian businesses to access the Chinese market directly, thus bypassing traditional trade barriers and broadening the customer base for Ethiopian exporters. Furthermore, digital payment systems such as mobile money and electronic banking have facilitated cross-border transactions, with over 50% of Chinese companies

investing in Ethiopia utilizing these platforms. Innovations in smart logistics, including blockchain technology and IoT devices, have also improved supply chain management, reducing costs and enhancing trade reliability. However, challenges remain. While significant improvements in broadband infrastructure and mobile network coverage have been noted, coverage is uneven; rural areas still lag behind urban centers. High-speed broadband access is limited, impacting the efficacy of e-commerce platforms. Moreover, although internet penetration has grown, affordability remains a barrier for lower-income populations, hindering access to digital tools and platforms.

Digital literacy rates have improved but there are still gaps, especially between urban and rural populations, which affect the effective use of ICT resources.

These findings underscore the transformative potential of ICT development in enhancing bilateral trade cooperation and economic integration between China and Ethiopia. It is crucial for both countries to embrace digital technologies, foster innovation, and implement supportive policy measures to leverage the opportunities presented by the digital economy, aiming for shared prosperity and sustainable development.

The significance of this study extends beyond its immediate findings; it highlights practical implications such as the necessity for targeted investments in ICT infrastructure, strategies to improve digital literacy, and measures to address the digital divide. While some studies may argue that trade relations are influenced by factors beyond ICT, this research illustrates that without enhancing ICT, the potential for increased trade cannot be fully realized.

To build on these findings, future research should focus on cross-border e-commerce and the implications of digital trade policies. Policymakers are urged to develop comprehensive strategies that include investment in rural connectivity and the promotion of e-commerce initiatives, which are essential for unlocking trade opportunities. Regular monitoring and evaluation will also be vital for understanding the evolving dynamics of ICT-enabled trade relations.

In conclusion, prioritizing ICT development is fundamental not only for enhancing bilateral trade but also for enabling sustainable economic growth in Ethiopia and the broader region. All stakeholders, including governments, businesses, and educational institutions, must collaborate to create a conducive environment for innovation and inclusivity in the digital landscape. This collaboration is essential for realizing the full potential of ICT-enabled trade relations and fostering resilience in economic systems in the 21st century.

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Authors' contributions

Thanks to Prof. Yao Lu for overseeing the study, providing feedback during the writing, and helping refine the methodology. I conducted the research, collected the data, and wrote the first draft, which we refined together. We both approved the final version. All authors contributed to interpreting the results, made critical revisions, and approved the final version for publication.

All authors contributed to the interpretation of the results, revised the manuscript critically for important intellectual content, and approved the final version to be published.

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No additional data are available.

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