



Digital Technologies and Trade Facilitation in Ethiopia: A Mixed-Methods Analysis of Blockchain, AI, and IoT Adoption

Chekole Sete Demeke

Dessie, Ethiopia
Yunnan University of Finance and Economics, Kunming, China

Received: April, 2025, Published: June, 2025

ARTICLE INFO

Keywords:

Digital Technologies; Ethiopia
Export Competitiveness; Technology
Adoption; Trade Facilitation

© 2025 Chekole Sete Demeke. This open-access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license, making research freely available to the public and supporting a greater global exchange of knowledge and human experiments.

Cite: Chekole Sete Demeke (2025). Digital Technologies and Trade Facilitation in Ethiopia: A Mixed-Methods Analysis of Blockchain, AI, and IoT Adoption. *Int. Journal of Management and Data Analytics*, 5(1), 176-190.
<https://doi.org/10.5281/zenodo.15591008>

ABSTRACT

This study investigates the potential of digital technologies to revolutionize trade facilitation and enhance export performance in Ethiopia. Addressing a critical gap in the literature, it moves beyond general assessments to analyze the adoption and application of blockchain, artificial intelligence (AI), and the Internet of Things (IoT) within Ethiopia's trade sector. A mixed-methods approach, incorporating a survey of 255 trade stakeholders and 20 focus group interviews, identifies opportunities and challenges associated with digital transformation. Data analysis reveals the potential of blockchain to enhance customs transparency and efficiency, AI to expedite cargo clearance and strengthen fraud detection, and IoT to provide improved supply chain visibility. However, the research also addresses crucial concerns, including cybersecurity risks (87%), data privacy (75%), and potential shifts in employment (60%). Specifically, survey data revealed that only 10% of firms currently use AI, despite 67% recognizing its value for fraud detection. Qualitative analysis of interview transcripts highlighted concerns about the high cost and complexity of implementing blockchain solutions, as well as the need for clearer regulatory frameworks and multi-stakeholder cooperation. The findings inform actionable policy recommendations aimed at fostering a supportive digital trade ecosystem in Ethiopia, offering insights for other developing economies. Ultimately, this research aims to provide insights for management decision-making regarding technology adoption and strategic planning within the Ethiopian trade sector.

1. INTRODUCTION

The economic potential of sub-Saharan Africa is significantly hampered by inefficiencies in trade logistics, resulting in over \$14 billion in lost export opportunities annually (World Bank, 2023). Ethiopia, the second most populous nation in Africa and a rapidly developing economy, is particularly affected by these challenges. Despite its substantial contribution to national GDP, Ethiopia's trade sector faces constraints because of outdated processes, inadequate infrastructure, and complex customs procedures (MoT, 2019; UNECA, 2021), hindering international competitiveness.

The expanding incorporation of digital technologies into commercial and societal frameworks is progressively acknowledged as a key driver for boosting trade effectiveness, lowering transactional expenditures, and fostering enhanced competitive capabilities (WTO, 2021). For landlocked, low-income nations, such as Ethiopia, embracing digital innovation presents a unique opportunity to overcome developmental hurdles and unlock new

pathways to inclusive trade growth. While existing scholarly work has largely concentrated on developed nations and major emerging economies (Kshetri, 2018; OECD, 2020), a notable lacuna remains in the comprehension of unique obstacles and prospects present within the Sub-Saharan African context.

Ethiopia's unique context, characterized by limited digital literacy, low Internet penetration, and infrastructural limitations, necessitates the development of tailored digital solutions. Prior research cautions against the indiscriminate application of technologies developed in different contexts, highlighting the importance of addressing local challenges and leveraging local opportunities to drive digital adoption in Africa (Desta 2019; Tadesse 2021).

Currently, the average export clearance time in Ethiopia is six days, significantly lagging behind global and regional benchmarks and indicating considerable inefficiencies (Tsegaye & Endris, 2011). These delays are often attributed to factors such as weak interagency coordination, complex documentation requirements, and a lack of real-time trade information. Although technologies such as blockchain,

artificial intelligence (AI), and the Internet of Things (IoT) hold promise for improving trade facilitation, their implementation in Ethiopia remains limited and requires further exploration.

Recognizing this potential, the Ethiopian government has launched the “Digital Ethiopia 2025” strategy, a national initiative aimed at digitizing key sectors to accelerate economic transformation. However, progress has been hindered by systemic challenges. As of 2021, Internet penetration in Ethiopia stood at only 20%, and the nation ranked 103rd out of 172 countries globally in cyber readiness. Despite existing obstacles, programs such as the Netherlands Trust Fund V (NTF V) play a crucial role in fostering the growth of technology startups and micro, small, and medium-sized enterprises (MSMEs) by providing essential resources for skills development and infrastructure enhancement.

This study addresses the gaps in the literature by providing an in-depth empirical analysis of how digital technologies, specifically blockchain, AI, and IoT, can be strategically applied to enhance trade facilitation and export performance in Ethiopia. This study focuses on local implementation challenges, stakeholder perceptions, and policy frameworks, employing a mixed-methods approach involving stakeholder interviews and survey data from exporters, customs officials, and digital service providers. Data collected during the interviews were analyzed using thematic analysis to understand the perceived benefits and challenges of using digital technologies by key stakeholders. Furthermore, the survey data were analyzed using regression analysis to quantify the impact of digital technology adoption on export performance. The findings provide evidence-based insights that are directly relevant to government policy.

This study holds relevance not only for Ethiopia but also for other African countries facing similar trade and digitalization challenges. It delivers evidence-based insights for policymakers and development partners seeking to harness digital tools for economic transformation, demonstrating the need for context-specific interventions, rather than replicating foreign models. Furthermore, the research contributes to the broader discourse on digital inclusion, with implications for global value chain integration, SME development, and regional competitiveness.

This study was guided by the following questions.

1. What is the current degree of adoption of digital technologies such as blockchain, AI, and IoT in Ethiopia’s trade sector?
2. What benefits and barriers do key stakeholders associate with the use of these technologies in trade-related processes?

3. What policy recommendations can promote sustainable and inclusive adoption of digital trade solutions in Ethiopia?

The subsequent sections of this paper are structured in the following manner: Section 2 provides a critical review of the extant literature; Section 3 details the methodological approach employed in the study; Section 4 presents the results obtained and their corresponding analysis; and finally, Section 5 offers concluding remarks, including suggested policy implications and potential avenues for future scholarly investigation.

2. LITERATURE REVIEW

2.1. Digital Technologies and Trade Facilitation: A Theoretical Perspective

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

Digital technologies are fundamentally reshaping the global trade landscape, offering significant potential to streamline procedures, enhance transparency, and lower transaction costs (OECD, 2020). Beyond automating legacy systems, digital transformation entails a structural redefinition of how trade processes are conducted, coordinated, and regulated across borders. In many economies, foundational technologies such as Electronic Data Interchange (EDI), e-customs, and web-based trade portals have catalyzed efficiency gains and improved governance (Arvis et al., 2016). However, frontier technologies—blockchain, artificial intelligence (AI), and the Internet of Things (IoT)—present even greater potential to enhance trade facilitation by enabling real-time monitoring, fraud detection, and enhanced data interoperability (UNCTAD, 2023).

In the Ethiopian context, however, the adoption of these technologies remains at an early stage, impeded by infrastructural, regulatory, and institutional challenges. Successful integration of digital solutions requires not only technological readiness but also coherent policy frameworks, organizational alignment, and stakeholder engagement (Hoekman, 2022). To systematically explore these dynamics, this study draws upon three interrelated theoretical frameworks: the Technology Acceptance Model (TAM), Diffusion of Innovation (DoI) Theory, and the Resource-Based View (RBV). Together, these frameworks provide a multi-dimensional lens for understanding the drivers and barriers of digital transformation in Ethiopia’s trade ecosystem.

- *Technology Acceptance Model (TAM):*

Davis's (1989) Technology Acceptance Model (TAM) proposes that an individual's adoption of technology is principally driven by their perceptions of its usefulness and ease of use. Within Ethiopia's trade sector, the relevance of TAM lies in assessing whether trade stakeholders—such as customs officers, exporters, and logistics providers—perceive emerging technologies as both beneficial and user-friendly. For example, while AI tools may offer advantages in fraud detection and cargo clearance, their actual adoption hinges on whether users find them intuitive and capable of solving immediate operational challenges.

This framework is particularly useful for Research Question 2, which investigates barriers to adoption. However, given TAM's limitations in accounting for broader institutional and socio-cultural factors (Venkatesh & Davis, 2000), this study incorporates contextual variables specific to Ethiopia, such as digital literacy gaps, unreliable ICT infrastructure, and limited access to capacity-building. These factors are critical for understanding whether stakeholders feel empowered to adopt and use technologies such as blockchain or IoT devices. Moreover, TAM allows for the analysis of cultural attitudes toward technological change, which often play a decisive role in technology acceptance in developing economies.

- *Diffusion of Innovation Theory (DoI):*

Rogers' (2003) Diffusion of Innovations (DOI) theory elucidates the process by which novel ideas and practices are disseminated within a population. This theory posits that the adoption of an innovation is influenced by several key perceived attributes, including its relative advantage compared to existing practices, its compatibility with existing values and needs, its perceived complexity, the degree to which it can be tested or experimented with (trialability), and the extent to which its results are visible to others (observability). This framework is instrumental in exploring Research Question 1: how digital technologies are currently being adopted across Ethiopia's trade value chains and what factors influence their diffusion.

In Ethiopia, early signs of adoption exist through initiatives like the implementation of electronic single windows and pilot digital customs clearance programs. Yet, diffusion is uneven, often stalling due to poor infrastructure, inadequate digital skills, and financial constraints. Comparative cases, such as Rwanda's successful rollout of e-customs systems (UNECA, 2021), suggest that Ethiopia could benefit from phased adoption strategies and knowledge transfer across regions.

DoI also underscore the importance of opinion leaders and institutional champions. In the Ethiopian trade sector, this may include government agencies, large-scale exporters, or donor-backed technology hubs that can serve as catalysts for wider adoption. This study examines which

actors serve as influential nodes in Ethiopia's trade innovation network, and how they can be leveraged to promote sustainable digital adoption.

- *The Resource-Based View (RBV):*

According to Barney's (1991) Resource-Based View (RBV), a firm's competitive advantage is predicated on its capacity to procure and effectively utilize resources that are valuable, rare, difficult to imitate, and non-substitutable (VRIN). In the realm of digital trade, these resources encompass both physical assets, such as sophisticated information and communication technology (ICT) infrastructure, and intangible assets, including robust data management expertise, effective digital leadership, and a skilled workforce.

This framework is central to Research Question 2, as it provides insights into the resource constraints Ethiopian firms face in adopting and benefiting from digital technologies. For example, while blockchain may offer transparency in customs procedures, its successful deployment depends on firms having both the technological infrastructure and the expertise to operate decentralized systems. The RBV also helps evaluate whether firms require external support, such as public-private partnerships, foreign direct investment, or donor-funded capacity-building programs, to build digital resilience.

Moreover, the RBV highlights the need to assess the strategic alignment between resource capabilities and export competitiveness. This study explores which resource gaps (e.g., cybersecurity skills, reliable internet access, or interoperable databases) are most critical in limiting Ethiopian firms' ability to leverage digital transformation for trade facilitation and export performance.

By integrating TAM, DoI, and RBV within the Ethiopian context, this study provides a robust analytical framework to assess digital transformation's impact on trade facilitation. Theoretical insights are grounded in practical challenges—including limited digital infrastructure, high technology adoption costs, and fragmented policy coordination—which collectively hamper the full realization of digital trade's benefits.

This literature review lays the foundation for empirical investigation and informs Research Question 3, which seeks to develop actionable, context-sensitive policy recommendations. These may include phased technology rollouts, investment in digital literacy and infrastructure, and the development of an inclusive regulatory ecosystem. Ultimately, Ethiopia's digital trade future will depend on its ability to synchronize technological potential with institutional readiness and stakeholder engagement.

2.2. Blockchain Technology: Enhancing Trade Facilitation Through Trust and Transparency

Blockchain technology, with its decentralized and tamper-proof ledger system, is increasingly viewed as a potentially transformative force in international trade, particularly for streamlining trade-facilitation processes (Kshetri, 2018). Blockchain offers a promising avenue for reducing fraud, minimizing errors, and accelerating cargo clearance by creating secure, transparent, and auditable transaction records across complex supply chains (Tapscott & Tapscott, 2016). This enhanced trust among diverse stakeholders, coupled with a reduced need for intermediaries, can lead to more efficient trade operations (Nakamoto 2008). Furthermore, the data generated from these blockchain systems can be analyzed using advanced techniques to identify bottlenecks, predict potential disruptions, and optimize supply chain performance.

Several pilot programs have showcased the practical applications of blockchain-based solutions for tracking goods, verifying their origins, and automating customs procedures (IBM, 2017). For example, the TradeLens platform, a collaboration between Maersk and IBM, uses blockchain to connect various participants in the supply chain, increasing visibility and reducing the burden of paperwork (TradeLens, 2020). Initial findings suggest that TradeLens implementation is associated with decreased administrative costs for participating organizations (Molnar, 2021).

Moreover, research indicates that blockchain has the potential to revolutionize cross-border payments and lessen reliance on traditional banking systems. Facilitating greater financial inclusion for small and medium-sized enterprises (SMEs) involved in international trade can enhance their ability to compete and thrive within the global market. (World Economic Forum, 2021).

The World Economic Forum (2021) estimated a potential reduction of USD 1.1 trillion in the global trade finance gap through blockchain adoption. However, the benefits of blockchain technology are inextricably linked to the availability of meaningful data. Without standardized data formats and robust analytics capabilities, blockchain's potential may be limited.

Despite these potential advantages, challenges related to scalability and interoperability remain, hindering widespread adoption and full realization of blockchain's benefits (OECD, 2022). These challenges are particularly acute in Africa, where variations in Internet access and technological capabilities across countries pose significant barriers to the seamless integration of blockchain solutions. A report by the African Union (2020) emphasizes the need for standardized regulatory frameworks and increased investment in digital infrastructure as critical factors for promoting blockchain adoption in trade across the continent. Data governance policies and the skills needed to manage and interpret blockchain data are in short supply.

These issues are especially relevant for Ethiopia, where Internet penetration is relatively low compared to other African nations (World Bank, 2023). This limited access may impede the effective deployment and utilization of blockchain-based trade solutions. Further scholarly investigation is warranted to elucidate potential solutions to these impediments and to explore the adaptation of blockchain technology to the unique requirements and infrastructural constraints of the Ethiopian trade sector. What data strategies are most effective in increasing the value of blockchain technology in trade in the Ethiopian context?

2.3. Artificial Intelligence in Trade: Automating Processes and Enhancing Decision-Making

Artificial Intelligence (AI), encompassing machine learning methodologies, is increasingly being recognized as a transformative force in modern trade systems. Its potential lies in accelerating cargo processing, strengthening fraud-detection mechanisms, and improving the accuracy of trade forecasting (World Customs Organization [WCO], 2019). AI-driven systems leverage the analysis of large datasets to identify anomalous transactions, evaluate risk profiles, and automate routine tasks, thereby enabling human capital to focus on complex and strategic decision-making (European Commission, 2018).

For instance, machine learning algorithms can be implemented to forecast demand variability, optimize logistical operations, and personalize consumer interactions (Manyika et al., 2013). AI-enabled chatbots can deliver immediate customer support, whereas predictive analytics empower firms to anticipate market trends and adapt their strategies accordingly (Huang et al., 2023). Empirical evidence from WCO (2019) suggests that AI-enhanced risk management systems can lead to substantial improvements in fraud detection rates, with potential increases of up to 70%.

However, the integration of AI into trade processes requires careful consideration of its ethical implications. Potential algorithmic biases and their disproportionate impacts on specific societal groups must be thoroughly examined and mitigated (Crawford, 2021). To cultivate trust and ensure accountability in the application of artificial intelligence, especially within developing economies like Ethiopia, it is crucial to prioritize transparency and explainability in AI-driven decision-making processes (Rudin, 2019). This is particularly important given the potential for heightened data biases and less mature regulatory structures governing AI applications in such contexts. As highlighted by O'Neil (2016), inherent biases within data can amplify existing risks and potentially undermine the intended benefits of AI adoption.

2.4. Internet of Things in Trade: Bridging the Physical and Digital Divide

The Internet of Things (IoT) presents a significant opportunity to revolutionize trade through enhanced real-time monitoring and control of cargo, thereby improving supply chain visibility and security (Atzori et al., 2010). By deploying sensors and tracking devices, stakeholders can continuously monitor location, temperature, humidity, and conditions throughout the supply chain (Vermesan & Friess, 2013). This granular, real-time data stream enables the optimization of logistical processes, mitigation of risks related to theft or damage, and adherence to complex regulatory frameworks (Sundmaeker et al., 2010). This is particularly relevant in Ethiopia, where infrastructure limitations and logistical challenges can significantly impact export performance.

Internet of Things (IoT) applications are diverse. For instance, the temperature of perishable goods can be meticulously monitored during transit, ensuring adherence to cold chain requirements and minimizing spoilage, thus preserving the product quality and market value (Gubbi et al., 2013). Furthermore, IoT facilitates the automation of warehouse operations, which has the potential to enhance efficiency, reduce labor costs, and improve inventory management (Evans, 2011). These improvements contribute to trade facilitation and potentially boost export performance. A case study by DHL (2017) suggests that IoT-enabled supply chains can reduce operating costs by up to 15%, demonstrating their potential economic impact.

However, the integration of the IoT also presents critical challenges. Data security and privacy are paramount concerns, requiring robust safeguards to prevent unauthorized access and misuse of sensitive supply chain information (Weber, 2010). Furthermore, the initial investment in IoT infrastructure, the need for skilled personnel to manage and maintain these systems, and potential issues regarding the interoperability between different IoT devices and platforms must be carefully considered (European Commission, 2009). The Ethiopian context, with its specific technological infrastructure and regulatory environment, necessitates careful assessment of these challenges and the development of tailored solutions. This review emphasizes the need for a comprehensive approach that considers both the potential benefits and the associated risks of IoT adoption in the Ethiopian trade sector.

2.5. Digital Technologies in Ethiopia: Opportunities and Challenges

While digital technologies hold significant promise for enhancing trade facilitation, realizing these benefits in Ethiopia necessitates careful consideration of the nation's specific context, challenges, and opportunities (UNECA 2021). This section addresses the current state of digital technology adoption in Ethiopia's trade sector, perceived benefits and challenges by stakeholders, and identifies

areas for policy intervention, drawing upon the relevant literature.

Several key themes emerge from the existing literature on digital transformation in Ethiopia's trade environment.

- *Infrastructure Deficiencies:*

Inadequate Internet penetration, unreliable electricity supply, and underdeveloped ICT infrastructure remain significant impediments to the broad digital transformation within Ethiopia (AfDB, 2019). These constraints limit the accessibility and effectiveness of digital trade solutions, particularly for businesses in rural areas. The African Development Bank (2019) estimates that substantial investments are required to bridge this infrastructure gap. Rectifying these shortcomings is paramount to ensuring the equitable uptake of digital technologies. This is especially critical given that unequal adoption rates have the potential to hinder long-term sustainable development.

- *Skills Gap:*

The scarcity of proficient personnel in domains like data analytics, software development, cybersecurity, and digital literacy impedes the successful deployment, administration, and expansion of digital trade infrastructures (ITU, 2019). This skills gap constrains Ethiopian firms' ability to capitalize on digital technologies to streamline trade processes and bolster export competitiveness. Consequently, focused educational and training initiatives are paramount to unlocking the full potential of digital transformation.

- *Regulatory and Policy Framework:*

The lack of a robust and articulated regulatory structure encompassing digital trade, data protection, cybersecurity protocols, and intellectual property rights generates ambiguity that can impede investment in digital technologies in Ethiopia (UNECA, 2020). Harmonized digital trade policies are needed to facilitate cross-border e-commerce, ensure data security, and promote a level playing field for businesses. The lack of clarity may be perceived as a significant challenge by stakeholders.

- *Mobile Technology Leverage:*

Given the high rates of mobile phone penetration in Ethiopia, mobile-based solutions present a valuable opportunity for expanding access to digital trade opportunities, especially for small and medium-sized enterprises (SMEs). Mobile money platforms can facilitate cross-border payments and reduce transaction costs, thereby promoting trade and financial inclusion (Aker & Mbiti, 2010). Leveraging mobile technology strategically is crucial for ensuring equitable access to digital trade benefits. It is important to note here on current issues in Ethiopia's mobile payment sector, as regulations are still being amended.

- *Current Digital Technology Adoption:*

Research is needed to ascertain the specific digital technologies currently being adopted within the Ethiopian trade sector. While anecdotal evidence suggests uptake of basic e-commerce platforms, the extent of adoption of advanced technologies like blockchain, AI, and IoT remains unclear. Understanding the current landscape is crucial for tailoring policy interventions and support programs.

Although extensive empirical research directly examining the influence of digital transformation on trade facilitation and export performance within Ethiopia remains scarce, initial indications suggest possible advantages. For instance, the Ethiopian Revenue and Customs Authority (ERCA) has introduced various digital strategies intended to optimize customs processes. Nevertheless, thorough assessments are necessary to ascertain the efficacy of these strategies and to pinpoint areas requiring enhancement.

The existing body of research underscores that while digital technologies present considerable prospects for Ethiopia's trade sector, they are also accompanied by substantial and complex challenges. Further research is needed to address the key gaps in our understanding, particularly regarding the adoption rates of specific digital technologies, the perceptions of Ethiopian stakeholders, and the development of effective policy recommendations. Specifically, it would be ideal to investigate the role of blockchain technology could contribute to enhancing security and traceability in Ethiopia's supply chains; moreover, determine best practices for AI to optimize logistics and customs processes, and what safeguards must be in place to protect data privacy; and to assess how Ethiopian SMEs can best leverage IoT-enabled solutions to improve inventory management and reduce operational costs.

2.6. Challenges and Risks of Digital Technologies in Trade

While digital technologies offer considerable potential for enhancing trade facilitation and export performance, their implementation in Ethiopia presents several challenges and risks that warrant careful consideration. These include the substantial upfront and ongoing costs associated with technology adoption, limitations in existing digital infrastructure and digital literacy among stakeholders, and vulnerabilities to cybersecurity threats that could compromise sensitive trade data (WEF, 2016). To effectively overcome these challenges, it is essential to allocate resources strategically towards the development of resilient digital frameworks, implement tailored training initiatives that foster the acquisition of requisite skills among the workforce, and establish exhaustive cybersecurity measures to safeguard against potential threats (as noted by the International Telecommunication Union in 2019).

Furthermore, the deployment of AI in trade-related processes raises ethical considerations, particularly regarding potential biases embedded within algorithms that could lead to discriminatory outcomes. Addressing such biases necessitates the development and implementation of transparent and accountable AI systems (O'Neil, 2016). The potential for job displacement resulting from automation also represents a significant concern. Proactive mitigation strategies, such as government-supported retraining and reskilling initiatives focused on emerging digital skills, are essential to minimize potential social and economic disruptions (Brynjolfsson & McAfee, 2014). Research into specific Ethiopian labor market dynamics and the potential impact of automation is needed to inform these strategies.

To mitigate the risk of widening societal disparities, the integration of inclusivity into digital transformation initiatives is of utmost importance. Addressing the digital divide through targeted strategies is essential to guarantee that all participants, encompassing small and medium-sized enterprises (SMEs) and marginalized populations, can equitably access and leverage the benefits of digital trade opportunities (UNDP, 2020). Further research is warranted to pinpoint specific obstacles to digital inclusion within Ethiopia's trade sector and to assess the efficacy of current interventions designed to foster equitable access. This could entail the examination of relevant governmental programs in Ethiopia aimed at assisting SMEs in incorporating digital technologies, as well as investigations into the effects of digital technologies on diverse demographic groups within the Ethiopian context.

2.7 Comments on Current Literature

Despite the growing body of literature on digital transformation in global trade, significant gaps remain in contextualizing these insights within Ethiopia's specific trade environment. Much of the existing research emphasizes the theoretical potential of technologies such as blockchain, AI, and IoT to enhance trade facilitation; however, empirical studies focused on their real-world application in low-income, landlocked countries like Ethiopia are sparse. For instance, while theoretical models such as the Technology Acceptance Model (TAM), the Diffusion of Innovation (DoI), and the Resource-Based View (RBV) provide valuable conceptual frameworks, the literature does not adequately explore how these models intersect with Ethiopia's unique constraints such as low digital literacy, inconsistent infrastructure, and institutional inertia. Moreover, although studies highlight the benefits of blockchain in improving transparency or AI in fraud detection, they often rely on success stories from developed countries or large emerging markets, with limited attention to how these technologies perform under the infrastructural and regulatory limitations present in Ethiopia.

Another notable gap lies in the limited empirical evaluation of pilot programs or digital initiatives launched by Ethiopian institutions, such as customs automation

systems. The literature lacks rigorous, data-driven assessments of these initiatives' effectiveness or scalability. Similarly, while several studies mention the importance of mobile technologies and SME inclusion, few offer detailed strategies tailored to Ethiopia's fragmented digital ecosystem or informal trade dynamics. In addition, the ethical, social, and labor implications of digital technologies, especially AI, are underexplored in the Ethiopian context, particularly in terms of bias, accountability, and job displacement.

Thus, this study fills a critical gap by empirically examining how digital technologies are adopted, perceived, and implemented across Ethiopia's trade sector. Future research should further investigate localized adoption patterns, stakeholder readiness, and the long-term impact of digital tools on competitiveness and inclusion, ensuring that technology-driven trade transformation is both practical and equitable.

3. METHODOLOGY

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper.

To thoroughly examine the influence of digital technologies on trade facilitation and export performance within Ethiopia, this research employed a mixed-methods strategy, combining both quantitative and qualitative data collection and analysis techniques. This approach was chosen because it allows for triangulation of findings, providing a richer and more nuanced understanding of the complex interplay between technology adoption, trade processes, and stakeholder perspectives. Specifically, the quantitative data provides a broad overview of adoption rates and perceived impacts, while the qualitative data offers in-depth insights into the underlying mechanisms and challenges (Creswell & Plano Clark, 2017). This mixed-method approach enables the investigation of the "what" (extent of technology adoption and export performance) through quantitative methods, and the "why" and "how" (underlying reasons and policy implications) through qualitative methods (Bryman, 2015).

3.1. Quantitative Data Collection

A survey instrument was distributed to a sample of 255 professionals within Ethiopia's trade industry to investigate the status of digital transformation. The participant pool encompassed a diverse range of stakeholders, including personnel from customs, export/import businesses, freight forwarding services, logistics firms, and governmental bodies. To guarantee proportional representation across varied sectors and geographical areas, a stratified random sampling methodology was employed. The questionnaire incorporated both closed-ended questions, offering structured response options, and open-ended questions,

allowing for more detailed qualitative feedback. Data was collected regarding the current level of digital transformation, the implementation of particular digital technologies, the advantages and obstacles perceived by stakeholders, and recommendations for policy enhancement. Attitudes and perceptions concerning digital technologies were evaluated using Likert scales, ranging from 1 (strongly disagree) to 5 (strongly agree).

3.2. Qualitative Data Collection

To comprehensively address the research questions, twenty focus group interviews were conducted with salient stakeholders to elicit nuanced insights. Participants were strategically chosen to represent diverse areas of expertise, including representatives from customs agencies, export management, technology development, and policy formulation. Each focus group comprised six to eight individuals. A semi-structured interview protocol guided the discussions, encompassing topics such as the contemporary landscape of digital transformation, specific implementations of blockchain, artificial intelligence, and the Internet of Things, anticipated advantages and disadvantages, and proposed policy interventions. Audio recordings of the interviews were made and subsequently transcribed to facilitate rigorous analysis.

3.3. Data Analysis

The quantitative data derived from survey questionnaires underwent analysis utilizing descriptive statistics, encompassing frequencies, means, and standard deviations, to provide a concise summary of respondent demographics and rates of technology adoption. Pearson's r correlation analysis was employed to investigate the relationships between variables related to digital transformation and indicators of trade facilitation. Furthermore, a multiple linear regression model was utilized to evaluate the influence of digital technologies on export competitiveness. This model incorporated independent variables, including specific metrics of digital technology adoption, alongside control variables such as firm size and export experience. To ensure the robustness of the regression results, diagnostic tests were conducted to verify assumptions of linearity, independence of errors, homoscedasticity, and normality of residuals. The Statistical Package for the Social Sciences (SPSS) version 25 facilitated all quantitative data analyses.

The qualitative data obtained from focus group interviews were subjected to thematic analysis, guided by the methodological framework proposed by Braun and Clarke (2006). This process entailed: (1) thorough familiarization with the data through iterative reading of transcripts; (2) generation of initial codes informed by the research questions and emergent themes; (3) identification of patterns and themes across the coded data; (4) critical review and refinement of the identified themes; (5) precise definition and clear naming of each theme; and (6) compilation of a final report incorporating illustrative quotations. To enhance rigor and trustworthiness, inter-

coder reliability was established by engaging two independent researchers to code a sample of the transcripts. Cohen's Kappa coefficient was computed to assess inter-coder agreement, with values indicative of substantial agreement (Landis & Koch, 1977). NVivo version 14 software was used to support the coding and analytical processes for the qualitative data.

4. RESULT AND DISCUSSION

4.1 Result

This section presents a synthesis of findings derived from a quantitative survey (N=255) and qualitative focus group interviews (20 groups), examining the current state of digital transformation in Ethiopia's trade sector and its impact on trade facilitation and export performance. Data analysis involved descriptive statistics for the survey data and thematic analysis for the focus group transcripts. This comprehensive assessment yields a sophisticated understanding of the extent of digital technology adoption in Ethiopian trade, alongside the perceived advantages, existing obstacles, and potential prospects.

4.1.1 Current State of Digital Technology Adoption

A dualistic pattern characterizes the integration of digital technologies in Ethiopia's trade sector, as evidenced by survey findings. Basic tools like email (85%) and web portals (70%) are widely used. However, more sophisticated technologies crucial for contemporary trade facilitation, including blockchain (15%), artificial intelligence (AI) (10%), and the Internet of Things (IoT) (8%), demonstrate significantly lower adoption rates (Table 1).

TABLE 1: ADOPTION RATES OF DIGITAL TECHNOLOGIES IN ETHIOPIA'S TRADE SECTOR (N=255)

Adoption Rates of Digital Technologies		
NO	Technology	Percentage of Adoptions
1	Email	85%
2	Web-based Portals	70%
3	Electronic Data Interchange (EDI)	45%
4	Blockchain	15%
5	Artificial Intelligence (AI)	10%
6	Internet of Things (IoT)	8%

Source: Survey Data, 2025

Analysis of the survey data indicates a predominance of basic technologies, suggesting a potential digital divide wherein more sophisticated tools are not being fully leveraged. Longitudinal data would be valuable to ascertain trends in technology adoption over time. The trend analysis can reveal the consistency of use of the current tech level over the last three to five years.

The qualitative data corroborated these findings, with focus group participants emphasizing the need for scalable adoption strategies and sustained usability of existing technologies in the face of market fluctuations. Example: some participants mentioned that EDI is good, but the challenge of its high setup cost creates a lot of burden on our side.

4.1.2 Perceived Benefits and Challenges of Digital Technologies

The quantitative data, as illustrated in Figure 1, highlights the perceived benefits of digital transformation among stakeholders. The thematic analysis of focus group transcripts revealed the following key challenges hindering the more widespread digital technologies:

- **Resistance to Change:** Traditional practices and a reluctance to abandon established workflows contributed to resistance to change within some segments of the trade sector.
- **Absence of a Clear Regulatory Framework:** The lack of a comprehensive and well-defined regulatory framework governing digital trade created uncertainty and hampered investment in digital technologies. Participants emphasized the need for clear guidelines on data privacy, cybersecurity, and cross-border data flows.

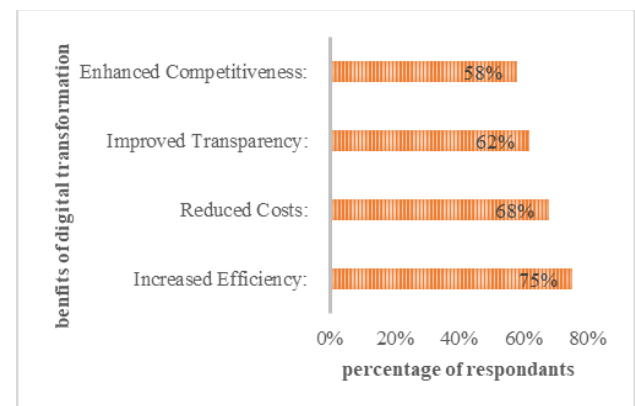


Figure 1. Perceived Benefits of Digital Technologies in Ethiopia's Trade Sector (N=255)

Source: Survey Data, 2025

Despite these challenges, focus group participants also acknowledged the transformative potential of digital technologies to:

- **Streamline Customs Procedures:** Automate and expedite customs clearance processes, reducing delays and costs.
- **Reduce Corruption and Improve Transparency:** Enhance accountability and minimize

opportunities for illicit activities through increased transparency and traceability.

- **Enhance Export Competitiveness:** Improve efficiency, reduce transaction costs, and enable access to new markets, thereby boosting export performance.
- **Attract Foreign Investment:** Create a more attractive investment climate by signaling a commitment to modernization and innovation.
- **Create New Job Opportunities:** Foster the growth of a dynamic digital economy, generating employment opportunities in areas such as software development, data analytics, and e-commerce.

4.1.3 Blockchain Technology for Improved Customs Procedures

A substantial majority (60%) of survey participants indicated a belief that blockchain technology possesses the capacity to enhance both transparency and efficiency within customs processes.

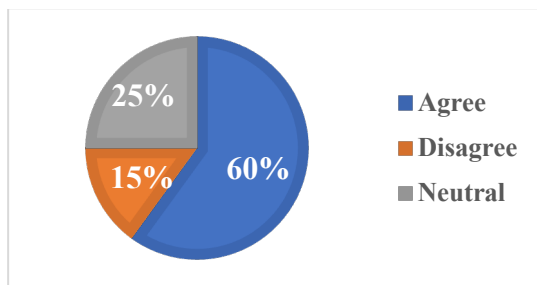


Figure 2. Potential of Blockchain in Customs Procedures

Source: Survey Data, 2025

The focus group interviews highlighted specific applications of blockchain in customs procedures, including:

- Tracking goods along the supply chain. ("It would be easy to show where the parts or the merchandise came from and when it left".)
- Verifying the authenticity of documents.
- Automating customs clearance processes.
- Reducing fraud and corruption.

However, concerns were also raised regarding the complexity of implementing blockchain and the need for collaboration among different stakeholders.

4.1.4 AI and Machine Learning for Expedited Cargo Clearance and Fraud Detection

The survey results indicated that 55% of respondents believe that AI and machine learning can play a significant

role in expediting cargo clearance and detecting fraud. The focus group interviews helped to better expand the potential of AI to not only address areas of expedited cargo clearance and fraud detection but also the potential implementation of other AI technologies.

TABLE 2: USE OF AI IN EXPEDITED CARGO CLEARANCE AND FRAUD DETECTION.

Use of AI in Expedited Cargo Clearance and Fraud Detection		
NO	Use of AI	Percentage (%)
1	Expediting Cargo Clearance	55%
2	Fraud Detection	67%
3	Predicting Trade Trends	43%
4	Automating Routine Trade Tasks	78%

Source: Survey Data, 2025

The focus group interviews highlighted the potential of AI to:

- Analyze large volumes of data to identify suspicious transactions.
- Assess risk and prioritize inspections.
- Automate routine tasks such as document verification.

A logistics manager stated, "AI can help us to identify high-risk shipments and focus our resources on those that are most likely to be involved in illegal activities." However, participants also expressed concerns about the accuracy and reliability of AI algorithms, as well as the potential for bias.

4.1.5 IoT Solutions for Real-Time Monitoring and Control of Cargo

The survey results showed that 48% of respondents believe that IoT solutions can contribute to real-time monitoring and control of cargo, improving supply chain visibility and security. However, participants also raised concerns about the cost of implementing IoT solutions and the need for interoperability between different systems.

The focus group interviews highlighted specific applications of IoT, including:

- Tracking the location, temperature, and condition of goods.
- Preventing theft and damage.
- Ensuring compliance with regulations.
- Optimization of logistics operations.

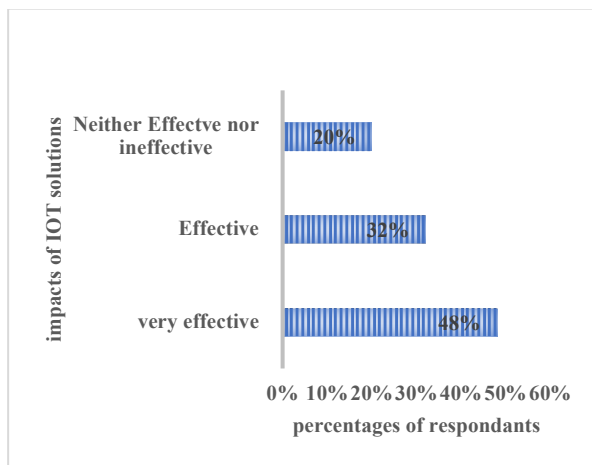


Figure 3. Impact of the IOT Solution for Real-Time Monitoring and Control of Cargo

Source: Survey Data, 2025

An export manager noted, "IoT can give us real-time visibility into our supply chain, allowing us to identify and address any problems before they escalate." However, participants also raised concerns about the cost of implementing IoT solutions and the need for interoperability between different systems.

4.1.5 Risks and Ethical Considerations

This investigation identified several potential risks and ethical considerations about the incorporation of digital solutions within Ethiopia's trade sector. Predominant among these concerns, as indicated by a substantial proportion of respondents, were cybersecurity vulnerabilities (87%), followed by anxieties surrounding data privacy (75%), potential job displacement (60%), and a general lack of trust in digital systems (42%).

TABLE 3: RISKS AND ETHICAL CONSIDERATIONS (%)

NO	Risks and Ethical Considerations on digital solutions in Ethiopian trade sectors	
	Risks and Ethical Considerations	Percentage (%)
1	Cybersecurity	87%
2	Data privacy	75%
3	Job displacement	60%
4	Lack of trust	42%

Source: Survey Data, 2025

Specifically, the apprehension regarding cybersecurity threats, such as unauthorized access and data breaches, was widespread. The implementation of robust and comprehensive cybersecurity protocols is therefore paramount to safeguarding sensitive trade information. Furthermore, a significant emphasis was placed on data privacy, with concerns articulated regarding the collection, storage, and utilization of personal data. Establishing

transparent and enforceable data privacy policies and regulations is crucial to protect individual rights and ensure ethical data handling practices.

The potential for job displacement, particularly affecting lower-skilled workers, was also a prominent concern. Investment in targeted training and education programs designed to facilitate workforce adaptation to the evolving demands of the digital economy is essential. Finally, fostering trust in digital technologies is crucial for their successful integration, addressing concerns related to potential manipulation or misuse and promoting user confidence in the reliability and integrity of these systems.

4.2 Discussion

4.2.1 Analyzing How This Study Relates to Ethiopia and Key Stakeholders

There were several key challenges to the digital transformation of the Ethiopian trade sector that key parties recognized, and this point should be at the forefront as more and more trade developments occur in a quickly developing economy.

The first point to take note of and review was the "Lack of digital infrastructure", as it was a common point that needed to be maintained and fixed.

TABLE 4: KEY CHALLENGES TO TRADE FACILITATION

NO	Key Challenges to Trade Facilitation	
	Key Challenges	Percentage (%)
1	Lack of digital infrastructure	83%
2	Limited digital skills	70%
3	Costly implementation	42%
4	Lack of trust	30%

Source: Survey Data, 2025

Those stakeholders who are part of the digital transformation (both internal to the country and external) all recognized a lack of digital skills among their various trade stakeholders.

The purpose of this study was to analyze how digital transformation will benefit the future of trade would including the risks and ethical considerations, to be carried out in the best way possible.

These particular topics would not be achievable without some key things in place, such as cybersecurity implementations, transparent AI technology, and open dialogue between stakeholders.

4.2.2 Analysis and Interpretation of Regression Results

The multiple linear regression model employed in this study aimed to assess the impact of several digital transformation initiatives on Ethiopia's export competitiveness, proxied by the Export Competitiveness

Index (ECI) proxy. The model's overall fit was evaluated using R-squared and F-statistics.

strong positive and statistically significant relationship with the ECI proxy ($B = 0.48$, $p < 0.001$). This suggests that efficiency gains are important determinants of export competitiveness in the study context.

Table 5: Analysis of regression results

Variable	Coefficient (B)	Standard Error	t-statistic	p-value	VIF
(Intercept)	10.5	2.1	5.0	<0.001	
X1: Web Portals	0.35	0.12	2.92	0.004	1.25
X2: Improved Efficiency	0.48	0.09	5.33	<0.001	1.45
X3: Blockchain Agreement	0.22	0.15	1.47	0.142	1.30
X4: AI Cargo Clearance	0.18	0.10	1.80	0.073	1.15
Model Summary					
R-squared	0.62				
Adjusted R-squared	0.61				
F-statistic	98.7				
p-value (F-statistic)	<0.001				
Number of Observations (N)	255				

Source: Survey Data, 2025

Model Fit

The regression model accounts for a substantial proportion of the variance in the ECI proxy, with an R-squared value of 0.62. The adjusted R-squared of 0.61 indicates that the model's explanatory power is robust and minimally affected by the inclusion of additional predictor variables. Furthermore, the model exhibits strong statistical significance, as evidenced by the F-statistic ($F = 98.7$, $p < 0.001$), supporting the assertion that the independent variables, when considered together, are significantly associated with the ECI proxy.

Individual Predictor Effects

- Web Portals (X1): The adoption of web portals (X1) exhibits a positive and statistically significant relationship with export competitiveness ($B = 0.35$, $p = 0.004$). This suggests that greater engagement with web-based trade platforms is associated with enhanced export performance. Specifically, a one-unit increase in web portal adoption is correlated with a 0.35 unit increase in the export competitiveness index (ECI) proxy, when controlling for other factors.
- Improved Efficiency (X2): As hypothesized, improved efficiency in trade processes exhibits a

- Blockchain Agreement (X3): The estimated coefficient for agreement on the potential of blockchain technology was not statistically significant at the conventional $\alpha = 0.05$ level ($p = 0.142$). Therefore, based on this model, there is insufficient evidence to conclude that the agreement surrounding the blockchain's potential significantly influences the ECI proxy.

Although the coefficient is positive, the result necessitates cautious interpretation.

- AI Cargo Clearance (X4): The variable representing the adoption of AI-driven cargo clearance systems yielded a positive coefficient, but its statistical significance was marginal ($p = 0.073$). This near significance suggests a potential, albeit weak, relationship with the ECI proxy. Further investigation is warranted.
- Intercept: The intercept (10.5) represents the predicted value of the ECI proxy when all independent variables are zero. However, its practical interpretation is limited within the context of this model.

Multicollinearity Assessment: Variance Inflation Factor (VIF) values were examined to assess the presence of multicollinearity. The VIF values were all under 1.5,

suggesting that multicollinearity was unlikely to pose a significant issue in this model.

4.2.3 key Findings Related to Existing Literature: Digital Transformation and Trade facilitation in Ethiopia

Digital transformation in trade facilitation presents a pivotal opportunity for Ethiopia to enhance its export performance and integrate more effectively into the global trading system. Grounded in the theoretical frameworks of the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, and the Resource-Based View (RBV), this study critically examines how digital technologies are being perceived and adopted within Ethiopia's trade sector.

The results illustrate a dichotomy between the widespread use of basic digital tools such as email and web portals, and the significantly lower adoption rates of advanced technologies like blockchain, AI, and IoT. This disparity signals a digital divide that reflects both infrastructural and capacity limitations. Drawing from TAM, stakeholders' reluctance to adopt advanced digital tools appears to be influenced by concerns over their usability and perceived benefits, exacerbated by low levels of digital literacy and limited training opportunities. Moreover, in line with the Diffusion of Innovation Theory, the study identifies trialability and observability as weak links in the technology diffusion process.

While foundational systems like Electronic Data Interchange (EDI) have gained traction, the lack of demonstrative pilot projects and phased rollouts for more complex technologies hampers their broader acceptance. The RBV framework further elucidates that many Ethiopian firms lack the critical resources, skilled labor, robust ICT infrastructure, and access to strategic knowledge that are necessary to transform digital technologies into sustained competitive advantage.

Key informants from focus groups consistently cited high implementation costs, insufficient cybersecurity frameworks, and the absence of coherent regulatory policies as major constraints. Nonetheless, the research also revealed a growing awareness of the transformative potential of these technologies, particularly in areas such as real-time cargo tracking, fraud prevention, and customs automation. These findings underscore the need for integrated policy interventions aimed at capacity building, infrastructure development, and institutional reform. By aligning strategic investments with theoretical insights, Ethiopia can overcome structural barriers and unlock the full potential of digital transformation to facilitate trade and foster inclusive economic growth. Hence, this study not only contributes to academic discourse but also offers actionable implications for policy and practice tailored to the Ethiopian context.

5. CONCLUSION AND RECOMMANDATIONS

5.1 Conclusion

This study illuminates the transformative potential of digital technologies in revolutionizing Ethiopia's trade sector, enhancing trade facilitation, and boosting export competitiveness in the global marketplace. Our findings provide compelling evidence that technologies such as blockchain, artificial intelligence (AI), and the Internet of Things (IoT) can streamline processes, significantly reduce transaction costs, and improve market access for Ethiopian businesses. However, realizing this ambitious vision requires a strategic and holistic approach that proactively addresses existing challenges and mitigates potential risks to ensure inclusive and sustainable development.

The success of digital transformation in Ethiopia hinges on cultivating a supportive ecosystem characterized by the following:

- **Robust Digital Infrastructure:** Accessible and reliable digital infrastructure spanning both urban and rural areas is paramount.
- **Skilled Workforce:** A workforce equipped with the necessary digital skills to effectively leverage these technologies is essential.
- **Adaptive Regulatory Framework:** A transparent and agile regulatory framework that fosters innovation while safeguarding data privacy and security.
- **Collaborative Partnerships:** Strong and collaborative partnerships among key stakeholders from the government, private sector, and academia.

A critical element of success lies in the thoughtful and context-specific adaptation of digital technologies to align with Ethiopia's unique developmental needs, resource constraints, and institutional frameworks. By proactively addressing these factors, Ethiopia can strategically position its trade sector to contribute to long-term economic growth and foster a deeper integration into the global trading system. To achieve sustainable and equitable economic development in the face of a rapidly evolving global economy, Ethiopia must prioritize strategies to mitigate risks while capitalizing on emerging technological opportunities. This requires a strong commitment to continuous learning, adaptation, and strategic investment in the digital economy.

5.2 Policy Recommendations

Based on the study's key findings and the current realities of the Ethiopian trade sector, the following actionable policy recommendations are proposed to guide Ethiopia's digital transformation journey and maximize its positive impact:

- 1) **Strategic Infrastructure Investment for Inclusive Connectivity:** Prioritize sustained and strategic allocation

of both public and private resources to significantly improve Internet access penetration, with a specific focus on underserved rural areas where connectivity remains a critical barrier to digital inclusion. Key priorities include expanding reliable mobile broadband networks (4G/5G), developing robust and secure data center infrastructure, and leveraging existing initiatives such as the Universal Access Fund to ensure equitable access and bridge the digital divide.

2) **Cultivating a digitally skilled workforce:** Implementing comprehensive vocational, technical, and higher education curricula meticulously designed to develop relevant and in-demand digital skills. This should encompass training in critical areas, such as data analytics, software development, cybersecurity, digital marketing, e-commerce platform management, and cloud computing. Critically, specialized training programs specifically targeting SMEs should be established to enhance their capacity to adopt and effectively utilize digital tools for trade.

3) **Agile and Adaptive Regulatory Framework:** Develop a comprehensive and consistent regulatory framework that addresses key facets of the digital economy, including e-commerce, data privacy, cybersecurity, and intellectual property rights. Emphasizes the creation of a flexible and agile framework that can adapt to rapidly evolving technologies and incorporate international best practices. Particular attention should be paid to harmonizing regulations with trade agreements and international standards to facilitate seamless cross-border trade.

4) **Fostering Public-Private Collaboration and Innovation Ecosystems:** Actively cultivate robust collaboration between government agencies (e.g., Ministry of Trade and Industry, Ministry of Innovation and Technology), the private sector (including startups and SMEs), educational institutions (universities and vocational schools), research institutions, and civil society organizations to drive innovation, facilitate the sharing of best practices, and develop tailored solutions that address Ethiopia's unique needs. This collaboration should be purposefully directed towards the creation and support of thriving technology and innovation hubs, fostering a vibrant startup ecosystem, and promoting the widespread adoption of digital technologies by traditional businesses.

5) **Empowering SMEs Through Awareness and Targeted Support:** Launch broad-based national awareness campaigns to educate stakeholders, including businesses, consumers, and government officials, about the benefits of digital transformation and encourage widespread adoption. Simultaneously, it provides targeted and impactful support to SMEs, including financial incentives (e.g., grants and tax breaks), tailored technical assistance (e.g., training and mentorship programs), and facilitated access to digital platforms and marketplaces to accelerate their participation in domestic and international digital value chains. This

support should be carefully tailored to the specific needs of SMEs in different sectors and regions of Ethiopia.

6) **Ethical AI and Inclusive Digital Development:** Develop clear ethical guidelines and standards for the responsible use of AI and other emerging digital technologies to ensure fairness, transparency, accountability, and inclusivity. This includes establishing robust mechanisms to effectively address algorithmic bias, rigorously protecting data privacy (aligned with leading international standards such as GDPR, adapted to the Ethiopian context), and proactively promoting digital inclusion for marginalized groups, including women and people with disabilities. This ethical framework should be developed through inclusive consultations with relevant stakeholders, including ethicists, policymakers, and civil society organizations.

By focusing on these key areas and implementing these specific steps, policymakers can create an environment that fosters innovation, promotes digital inclusion, and unlocks the full potential of digital transformation to create a more efficient, transparent, and competitive trade sector, thereby contributing to Ethiopia's sustainable economic growth and development. Success depends on a sustained commitment to these principles and a willingness to adapt policies to the evolving digital landscape. Furthermore, the ongoing monitoring and evaluation of these policies are crucial to ensure their effectiveness and relevance in the face of rapid technological change.

5.3 Limitations and Future Research

The findings of this study are inherently limited by the sample size. Although the sample size was substantial, it may not comprehensively represent the heterogeneity of all Ethiopian trade stakeholders. The potential for sampling bias exists, particularly in the possible under-representation of informal traders, rural businesses, and micro-enterprises, which constitute a significant portion of the Ethiopian economy. The data collection challenges inherent in the Ethiopian context may also introduce bias.

Future research should broaden the scope of inquiry to encompass emerging technologies beyond blockchain, AI, and IoT. This includes evaluating the potential impact of additive manufacturing (3D printing), advanced robotics, and other cutting-edge technologies on trade and manufacturing competitiveness in Ethiopia. Critically, longitudinal studies employing rigorous quantitative metrics are required to accurately assess the actual effects of digital technologies on trade facilitation, export performance, and broader economic development outcomes. These studies should carefully control for potential confounding variables such as macroeconomic conditions and policy changes. Future studies should also consider the potential for future bias in algorithms and policies when addressing transformations driven by digital technologies.

To further enrich future research and provide a more nuanced understanding of the opportunities and challenges associated with digital transformation in the Ethiopian context, we recommend the following:

- In-depth case studies focusing on specific sectors (e.g., textiles and agriculture) that are critical to the Ethiopian economy.
- Exploration of the Impact of Mobile Payment Solutions on Trade Inclusivity.
- Gendered analyses examining the differential effects of digital transformation on women-owned businesses.
- Cross-national comparisons with similar developing African economies

Finally, future research should investigate the potential unintended consequences of digital transformation, such as job displacement and increased digital inequality, and explore policy options to mitigate these risks. This includes studies of the impact of automation on specific sectors and the development of strategies for workforce retraining and reskilling.

ACKNOWLEDGMENT

I would like to first acknowledge God for the grace that allowed me to undertake this research. I thank my beloved family for their love and encouragement, a constant source of strength.

REFERENCES

- [1] Abrahams, S. (2019). The impact of electronic single window systems on trade facilitation in Kenya. *Journal of African Trade*, 6(1), 45–62.
- [2] African Development Bank. (2019). Ethiopia's economic outlook. <https://www.afdb.org/en/countries/east-africa/ethiopia/ethiopia-economic-outlook>
- [3] Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. *Journal of Economic Perspectives*, 24(3), 207–232.
- [4] Arvis, J.-F., Duval, Y., Shepherd, B., & Utoktham, C. (2016). Trade costs in the developing world: 1996–2010. *World Trade Review*, 15(4), 549–573.
- [5] Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, 54(15), 2787–2805.
- [6] Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99–120.
- [7] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
- [8] Bryman, A. (2015). *Social research methods* (5th ed.). Oxford University Press.
- [9] Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. W. W. Norton & Company.
- [10] Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- [11] Crawford, K. (2021). *The atlas of AI: Power, politics, and the planetary costs of artificial intelligence*. Yale University Press.
- [12] Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). Sage Publications.
- [13] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340.
- [14] DHL. (2017). IoT in the supply chain. https://www.dhl.com/content/dam/dhl/global/core/core_responsibility/documents/dhl_trendreport_iiot_in_supplychain.pdf
- [15] European Commission. (2018). Artificial Intelligence for Europe. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0237>
- [16] Evans, P. C. (2011). How the Internet of Things will revolutionize manufacturing. *Cisco White Paper*, 1–11.
- [17] GSMA. (2020). The mobile economy: Sub-Saharan Africa 2020. <https://www.gsma.com/mobileeconomy/sub-saharan-africa-2020>
- [18] Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), 1645–1660.
- [19] Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods*, 18(1), 3–22.
- [20] Hoekman, B. (2022). Digital trade and development: Policy options. *World Bank Policy Research Working Paper* (No. 9964).
- [21] Huang, M. H., Rust, R. T., & Maksimovic, L. (2023). The feeling economy: Managing feelings through algorithms and AI. *Journal of the Academy of Marketing Science*, 51(1), 1–18.
- [22] IBM. (2017). Building trust and transparency in trade finance with blockchain. <https://www.ibm.com/blogs/blockchain/2017-building-trust-and-transparency-in-trade-finance-with-blockchain/>
- [23] International Labour Organization. (2019). Skills for a brighter future: Analysis of national experiences. https://www.ilo.org/global/topics/skills-and-employability/WCMS_713338/lang--en/index.htm
- [24] International Telecommunication Union. (2019). *Measuring the information society report*. ITU.
- [25] Kshetri, N. (2018). Blockchain and sustainable supply chain management in a developing country context. *International Journal of Information Management*, 39, 234–242.
- [26] Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159–174.
- [27] Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P., & Marrs, A. (2013). *Disruptive technologies: Advances that will transform life, business, and the global economy*. McKinsey Global Institute.
- [28] Ministry of Trade, Ethiopia. (2019). *Ethiopia's trade facilitation strategy*. Ministry of Trade.
- [29] Molnar, M. (2021). Measuring the impact and benefits of TradeLens. <https://www.maersk.com/news/2021/01/21/tradelens-reaches-new-milestones-in-its-mission-to-digitise-global-trade>
- [30] Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system. <https://bitcoin.org/bitcoin.pdf>
- [31] Organisation for Economic Co-operation and Development. (2020). Trade facilitation indicators. <https://www.oecd.org/trade/topics/trade-facilitation/trade-facilitation-indicators/>
- [32] Organisation for Economic Co-operation and Development. (2022). *Blockchain technology and global value chains*. OECD Publishing.
- [33] O'Neil, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy*. Crown.
- [34] Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- [35] Rudin, C. (2019). Stop explaining black-box machine learning models for high-stakes decisions and use interpretable models instead. *Nature Machine Intelligence*, 1(5), 206–215.

- [36] Sundmaecker, H., Guillemin, P., Friess, P., & Woelfflé, S. (2010). Vision and challenges for realizing the Internet of Things. In European research cluster on the Internet of Things (pp. 34–66).
- [37] Tapscott, D., & Tapscott, A. (2016). Blockchain revolution: How the technology behind Bitcoin is changing money, business, and the world. Penguin.
- [38] TradeLens. (2020). TradeLens annual report. <https://www.maersk.com/solutions/tradelens/>
- [39] United Nations Conference on Trade and Development. (2023). Digital economy report 2023. UNCTAD.
- [40] United Nations Development Programme. (2020). Human development report 2020: The next frontier—Human development and the Anthropocene. UNDP.
- [41] United Nations Economic Commission for Africa. (2020). Assessing progress on regional integration in Africa VIII: Towards digital financial integration. <https://repository.uneca.org/handle/10855/43450>
- [42] United Nations Economic Commission for Africa. (2021). Economic report on Africa 2021: Addressing the risks and opportunities of the digital age. https://www.un.org/sites/un2.un.org/files/2021_economic_report_on_africa_eng.pdf
- [43] Vermesan, O., & Friess, P. (Eds.). (2013). Internet of Things: Converging technologies for smart environments and integrated ecosystems. River Publishers.
- [44] Weber, R. H. (2010). Internet of Things – New security and privacy challenges. *Computer Law & Security Review*, 26(1), 23–30.
- [45] World Bank. (2021). Digital development report 2021: Connecting for inclusion. World Bank.
- [46] World Customs Organization. (2019). AI in customs: A practical guide. WCO.
- [47] World Economic Forum. (2016). The Global Information Technology Report 2016. WEF.
- [48] World Economic Forum. (2021). Blockchain solutions for sustainable trade finance. WEF.
- [49] World Trade Organization. (2021). World trade report 2021: Economic inclusion. WTO.