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Hesitant Fuzzy-BWM Risk Evaluation Framework for E-Business Supply Chain Cooperation for China–West Africa Digital Trade

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Abstract

This paper examines the risks linked to E-business collaboration between China and West Africa, with particular emphasis on Ghana as a pivotal digital commerce centre. This research employs the Hesitant Fuzzy Best–Worst Method (HF-BWM) to systematically identify and prioritise the institutional, technological, sociocultural, and legal issues affecting cross-border e-business operations. This study combines Transaction Cost Theory (TCT), the Technology Acceptance Model (TAM), and Commitment–Trust Theory to create a comprehensive framework for analysing the interplay of these risks and their effects on transaction costs and company sustainability. The findings indicate that institutional risks constitute the most substantial obstacles, with deficient digital transaction legislation and inadequate data governance recognised as the principal drivers of uncertainty and increased transaction costs. The research indicates that these institutional challenges necessitate immediate focus, as they immediately affect corporate operations, especially in international digital commerce. Technological risks, such as cybersecurity vulnerabilities, insufficient IT skills, and deficiencies in digital infrastructure, were identified as the second most critical factors, leading to considerable operational disruptions and heightened expenses. Sociocultural hazards, such as language difficulties and varying consumer behaviours, were recognised as moderate concerns that, although significant, exert a weaker cumulative impact than technological and institutional challenges. Eventually, legal risks, especially concerning cybercrime legislation and the protection of intellectual property, were identified as substantial complicators of e-business activities, increasing the intricacy of legal compliance and cross-border contract enforcement. The results underscore the imperative for regulatory reforms, investments in cybersecurity, and methods for cultural adaptation to alleviate the identified risks and promote sustainable growth in China–West Africa e-business relationships. This study offers practical insights for governments, business leaders, and investors to effectively manage the intricate risk landscape and make educated decisions that foster enduring collaboration and trust between China and West Africa in digital trade.

Keywords: China–West Africa cooperation; e-business supply chain; digital trade; Best–Worst Method (BWM); technique for order of preference by similarity to ideal solution (TOPSIS); Manhattan distance



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1. Introduction

The rapid expansion of e-business has fundamentally transformed international trade, creating new opportunities and challenges, particularly in the interactions between developed and emerging economies. As a global leader in digital infrastructure and technology, China has leveraged its vast consumer base, advanced logistics, and innovative platforms to dominate the global digital economy [1]. In parallel, West Africa, led by Ghana's emergence as a digital hub, has become an increasingly attractive market for e-business growth. Ghana's strategic location, youthful population, and proactive digital policies position it as a gateway for international digital commerce in the region [2]. Two major initiatives underscore the relevance of this partnership: the African Continental Free Trade Area (AfCFTA) and China's Belt and Road Initiative (BRI). The AfCFTA, headquartered in Ghana, aims to establish a unified market for goods and services across Africa, promoting economic integration and facilitating cross-border trade, particularly in the digital and e-commerce sectors [3]. The BRI, meanwhile, promotes infrastructural and digital connectivity, offering Chinese businesses a platform for expanding their digital services throughout Africa.

Together, these initiatives are reshaping the landscape of China–West Africa e-business cooperation, promising mutual economic growth, technological advancement, and increased market access. However, despite these promising prospects, the partnership faces significant and multifaceted risks. Technological vulnerabilities, such as cybersecurity threats and digital infrastructure gaps, expose businesses to data breaches and operational disruptions. Regulatory inadequacies, including inconsistent digital transaction frameworks and weak data governance, create uncertainty for cross-border transactions. Legal uncertainties, particularly around data protection, privacy, and intellectual property, further complicate business operations. Sociocultural differences, such as language barriers, divergent consumer behaviours, and cultural misalignments in digital platforms, add further complexity to cross-border e-business [4]. These risks are not merely theoretical; they have tangible impacts on the efficiency, trust, and sustainability of e-business collaborations. They increase transaction costs, deter investment, and limit the potential for innovation and growth. For Chinese businesses operating in Ghana and the broader West African market, these challenges can result in competitive disadvantages, stalled projects, and missed opportunities for both sides. While previous research has explored various aspects of e-business and digital trade, a critical gap remains: there is no comprehensive, systematic framework for identifying, categorizing, and prioritizing the specific risks associated with China–West Africa e-business cooperation.

Existing studies address these risks in isolation or focus on broader economic or technological factors, without integrating them into a cohesive risk management model tailored to this unique context. This absence of a holistic risk assessment limits the ability of policymakers, business leaders, and investors to develop targeted strategies that can effectively mitigate risks and foster sustainable cross-border e-business growth. While this study is grounded primarily in Transaction Cost Theory (TCT), which explains how various risks elevate transaction costs in cross-border e-business, it also draws on the Technology Acceptance Model (TAM) and Commitment–Trust Theory to capture the behavioural and relational dimensions of risk in digital trade. This integrated framework enables a more comprehensive understanding of how institutional, technological, sociocultural, and legal risks interact to shape e-business outcomes between China and West Africa [5]. By applying this integrated framework with TCT as its anchor, this research provides a robust theoretical lens for understanding how institutional, technological, sociocultural, and legal risks translate into increased transaction costs and how these can be managed for more efficient and sustainable cooperation. From a practical perspective, this study responds to the urgent need for actionable insights in risk management. As digital trade between China

and Ghana accelerates, public and private sector stakeholders require evidence-based tools to identify, prioritize, and address the most pressing risks. This is essential not only for protecting investments and ensuring compliance but also for building trust, enhancing competitiveness, and supporting the long-term sustainability of e-business partnerships.

The structure of this paper is as follows. Section 2 presents a review of the literature. In Section 3, the methodology of the study is presented. Section 4 presents the results. Section 5 concludes the research.

2. Literature Review

2.1. The Concept of China–West Africa Cooperation

The cooperation between China and West Africa in e-business represents a dynamic and multifaceted partnership that transcends traditional trade, including technological transfer, capacity building, and infrastructural development. This collaboration is deeply embedded within broader strategic frameworks such as China's Belt and Road Initiative (BRI) and the Forum on China–Africa Cooperation (FOCAC), which collectively aim to enhance economic integration and connectivity across Africa [6]. The BRI, in particular, has been instrumental in promoting digital trade by investing heavily in digital infrastructure such as broadband networks, data centres, and smart logistics hubs that are essential for the efficient functioning of e-business platforms [7]. Ghana exemplifies this cooperation's potential as one of West Africa's most digitally advanced countries and a regional hub for e-commerce and digital innovation. Its strategic location, youthful and tech-savvy population, and proactive government policies have positioned Ghana as a gateway for China's digital expansion into West Africa [8]. The African Continental Free Trade Area (AfCFTA), headquartered in Ghana, further amplifies this potential by creating a unified market for goods and services, including digital products, across the continent [9]. This synergy between AfCFTA and BRI initiatives underscores the strategic importance of Ghana in China–West Africa e-business cooperation. Capacity building is another critical dimension of this partnership. Initiatives such as the Beijing Declaration of the Ministerial Forum of China–Africa Health Development emphasize vocational and technical training to enhance human capital in digital skills, vital for sustaining e-business growth [10]. These efforts address the skills gap that often hampers the adoption and effective use of digital technologies in emerging economies.

Ghana is selected as a case study not only for its advanced digital infrastructure but also as a representative yet progressive node in the West African e-commerce ecosystem. Compared to Nigeria, the largest digital market in Africa, Ghana has a more stable regulatory environment and higher digital payment adoption (78% vs. 45%) [8]. Relative to Côte d'Ivoire and Senegal, Ghana has more mature e-commerce legislation, including the Data Protection Act (2012) and Electronic Transactions Act (2008). However, unlike these nations, Ghana faces unique cross-border integration challenges due to its role as the AfCFTA host, making it a strategic site for studying China–West Africa digital trade risks. Findings from Ghana thus offer a high-capacity baseline; in countries with weaker institutions, the relative impact of institutional and legal risks may be even greater, underscoring the framework's regional relevance and scalability.

Despite these promising developments, significant challenges remain. Regulatory gaps, including inconsistent digital trade policies and weak enforcement mechanisms, create uncertainty for businesses operating across borders. Cybersecurity threats pose risks to data integrity and consumer trust, while the digital divide, especially between urban and rural areas, limits equitable access to e-business opportunities [11]. These challenges highlight the necessity of collaborative governance frameworks that ensure the equitable distribution of benefits, strengthen local capacities, and manage risks effectively. This

study is situated within this context, aiming to identify and prioritize the risks faced by Chinese e-business firms in Ghana, thereby contributing to more sustainable and mutually beneficial cooperation.

2.2. E-Business Risks in China–West Africa Cooperation

The rapid expansion of China–West Africa e-business cooperation over the past two decades has brought significant economic opportunities and a complex array of risks that threaten operational success and sustainability. Understanding and managing these risks is crucial for reducing transaction costs, building trust, and fostering long-term growth in digital trade.

Institutional Risks are paramount among these challenges. They stem from the quality, stability, and coherence of the institutional environment in which e-businesses operate [12]. In Ghana and the broader West African context, the absence of comprehensive e-business policies, inadequate digital transaction regulations, limited data governance, and weak e-government support create an unpredictable business environment [13]. According to Transaction Cost Theory (TCT), such institutional weaknesses increase uncertainty and information asymmetry, escalating transaction costs related to searching for reliable partners, negotiating contracts, and enforcing agreements [14]. The study's empirical findings confirm institutional risk as the most significant concern, with issues like inadequate digital transaction regulations and insufficient data governance receiving the highest priority. This underscores the urgent need for policy harmonization and institutional strengthening to facilitate smoother digital transactions and reduce operational uncertainties.

Technological Risks encompass challenges related to adopting, implementing, and managing technology in e-business operations [15]. These include cybersecurity threats, a lack of skilled IT personnel, and deficiencies in digital infrastructure, such as unreliable internet connectivity and inadequate payment systems. In Ghana, despite notable progress, digital infrastructure gaps and cybersecurity vulnerabilities remain critical barriers to seamless e-business operations. TCT explains that these technological vulnerabilities increase operational uncertainties and the likelihood of disruptions, translating into higher transaction costs due to additional safeguards, monitoring, and recovery mechanisms [16]. Addressing these risks requires investments in hardware and software, human capital development, and robust cybersecurity protocols. Sociocultural Risks arise from interacting with diverse cultural, social, and behavioural norms across China and West Africa. Language barriers, differences in consumer behaviour, cultural misalignments in user experience design, resistance to digital payment methods, and perceptions of digital neo-colonialism complicate trust-building and cooperation. These factors increase uncertainty and opportunistic behaviour, elevating transaction costs as firms expend more resources on communication, adaptation, and conflict resolution. The study highlights that sociocultural risks significantly affect cross-border e-business operations, emphasizing the need for culturally sensitive strategies and localized digital solutions to mitigate these challenges and enhance cooperation.

Legal Risks involve uncertainties related to the legal and regulatory frameworks governing e-business transactions [17]. In West Africa, limited cybercrime legislation, intellectual property rights enforcement challenges, and divergent legal cultures create an unstable legal environment for Chinese firms. These weaknesses increase compliance costs and complicate contract enforcement, consistent with TCT's view that legal uncertainty inflates monitoring and enforcement costs [18]. Strengthening legal frameworks and harmonizing regulations are thus critical for reducing legal risks and fostering a secure environment for e-business cooperation. The study's focus on Ghana leverages its strategic importance as a digital hub in West Africa, making the findings highly applicable for

policymakers and business leaders aiming to foster sustainable e-business growth. The research offers actionable insights that enable targeted risk management by employing a hierarchical decision model and the Best–Worst Method (BWM) to prioritize risks. This approach addresses a critical gap in the literature, which often treats e-business risks in isolation without a systematic framework tailored to the unique China–West Africa context.

While existing studies have explored aspects of e-business risks in Africa, they often treat these risks in isolation and lack a systematic, integrated framework for cross-border digital trade. This study fills a critical gap by (1) developing a comprehensive risk taxonomy for China–West Africa cooperation, (2) applying the HF-BWM method to prioritize risks with high precision under uncertainty, and (3) integrating TCT, TAM, and Commitment–Trust Theory to explain the interplay of institutional, technological, sociocultural, and legal risks, offering both theoretical advancement and practical utility.

2.3. Theoretical Framework

This study integrates Transaction Cost Theory (TCT) as the primary economic framework, complemented by the Technology Acceptance Model (TAM) for behavioural insights and Commitment–Trust Theory for relational dynamics. This triad addresses institutional, technological, sociocultural, and legal risks holistically.

2.3.1. Transaction Cost Theory (TCT)

Transaction Cost Theory (TCT), pioneered by Fragomeni et al. [19], asserts that organizations exist to minimize the costs associated with economic exchanges. As the core lens, TCT explains how institutional and legal risks amplify transaction costs through uncertainty and enforcement challenges. For example, Ghana’s regulatory gaps force firms to invest in due diligence, raising operational costs [20]. These transaction costs include searching for information, negotiating and enforcing contracts, monitoring compliance, and managing opportunism. In cross-border e-business, these costs are amplified by institutional voids, regulatory inconsistencies, information asymmetry, and cultural distance. In China–West Africa e-business cooperation, TCT is especially salient. This study’s empirical findings, based on a sample of 40 e-business managers and practitioners across Ghana’s consumer electronics, telecommunications, digital payment, and online retail sectors, reveal that institutional risks are the most significant barrier to efficient cross-border e-business (global weight: 0.363). For example, the absence of coherent e-business policies, inadequate digital transaction regulations, and limited data governance create an unpredictable and uncertain environment. These institutional weaknesses force firms to spend more resources on due diligence, compliance, and dispute resolution, which raises the overall cost of doing business.

Moreover, the lack of harmonized regulatory frameworks between China and Ghana means that Chinese firms must navigate a patchwork of local rules, often without clear guidance or legal recourse. This increases compliance costs and exposes businesses to the risk of regulatory arbitrage and sudden policy shifts. From a TCT perspective, these risks make the market less attractive for investment and innovation, as firms must allocate more resources to risk mitigation rather than value creation. TCT also illuminates the importance of reducing information asymmetry and uncertainty. In Ghana, for instance, inconsistent enforcement of digital transaction regulations and data privacy laws can make it difficult for Chinese firms to verify the legitimacy of local partners or ensure the security of cross-border data flows. This increases the risk of opportunistic behaviour and fraud, further elevating transaction costs. This study operationalizes TCT by systematically ranking and prioritizing the risks that most significantly elevate transaction costs by employing a hierarchical decision model and the Best–Worst Method (BWM). The insights generated are actionable,

enabling managers and policymakers to target institutional reforms and capacity-building initiatives that directly address the most critical sources of inefficiency and uncertainty in the e-business environment. This approach advances theoretical understanding and offers practical risk management tools in rapidly evolving digital markets.

2.3.2. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), introduced by Unal and Uzun [21], provides a behavioural lens for understanding how individuals and organizations adopt and use new technologies. The TAM extends TCT by addressing how technological risks (e.g., cybersecurity gaps) influence perceived usefulness and ease of use. This behavioural layer explains why infrastructural deficits in Ghana elevate transaction costs via low adoption rates. The TAM posits that two primary factors, perceived usefulness and perceived ease of use, determine whether a technology will be accepted and integrated into daily operations. This model is especially relevant in digital transformation in emerging markets, where technological readiness and user acceptance are not always guaranteed. Despite significant progress in digital infrastructure in Ghana, technological risks remain a substantial barrier to the widespread adoption of e-business solutions (global weight: 0.286). The study's participants highlighted challenges such as a lack of IT expertise, cybersecurity threats, and persistent deficiencies in digital infrastructure.

These issues directly impact perceived ease of use and usefulness, as unreliable internet connectivity, frequent system downtimes, and inadequate technical support can frustrate users and erode confidence in digital platforms. Sociocultural factors further compound these technological challenges. Language barriers, resistance to online payments, and cultural misalignments in user interface design can make digital platforms seem alien or untrustworthy to local consumers. For instance, Ghana's diverse linguistic landscape and varying levels of digital literacy mean that platforms designed for Chinese or Western markets may not resonate with Ghanaian users. As a result, even technologically sound solutions may fail to gain traction if they are not tailored to local preferences and needs. The TAM also highlights the importance of user training and capacity-building. The lack of IT expertise among business operators and consumers often leads to the underutilization of digital tools, even when infrastructure is available. The study's findings underscore the need for targeted interventions such as digital literacy programs, localized user support, and culturally adapted interface design to enhance perceived ease of use and usefulness among Ghanaian users. By incorporating the TAM into the analysis, this study recognizes that risk management in e-business must go beyond technical fixes. It must also address the psychological and social dimensions of technology adoption. This means investing in user education, localizing digital content, and designing intuitive and culturally relevant interfaces. The study's findings underscore the importance of integrating the technical and human factors influencing e-business success.

2.3.3. Commitment–Trust Theory

Commitment–Trust Theory resolves TCT's limitations in sociocultural contexts by emphasizing trust as a cost-reduction mechanism. For instance, legal ambiguities in Ghana are mitigated through relational capital, reducing enforcement costs. Commitment–Trust Theory, articulated by Vătămănescu et al. [22], emphasizes that successful business relationships, especially in cross-border and digital contexts, are built on two foundational pillars: commitment and trust. In environments characterized by legal uncertainty, regulatory inconsistency, and cultural diversity, trust becomes a critical asset that can reduce perceived risks and facilitate long-term cooperation. Legal risks, such as limited cybercrime legislation, weak intellectual property protection, and divergent legal cultures, were identified by

study participants as significant obstacles to building trust between Chinese and Ghanaian partners (global weight: 0.174). For example, Ghana's lack of clear legal frameworks for digital transactions and data protection creates ambiguity around liability, dispute resolution, and enforcement. This uncertainty can deter investment and limit the willingness of firms to enter into long-term collaborations. Commitment–trust theory suggests that building and sustaining trust requires more than formal contracts. It involves transparent communication, shared values, and consistently demonstrating reliability and fairness. In the context of China–Ghana e-business cooperation, firms must invest in relationship-building activities, such as joint training programs, regular stakeholder engagement, and the co-creation of culturally sensitive business practices.

The theory also highlights the role of social capital in mitigating legal and sociocultural risks. By fostering networks of mutual support and shared understanding, firms can create informal mechanisms for dispute resolution and knowledge sharing that complement formal legal structures. The study's findings reinforce that trust and commitment are desirable outcomes and essential prerequisites for sustainable and mutually beneficial e-business partnerships. Furthermore, Commitment–Trust Theory provides a framework for understanding how reputational capital and long-term orientation can substitute for formal legal protections in environments where the latter are weak or absent. In Ghana, where the enforcement of digital contracts and intellectual property rights may be inconsistent, a business partner's reputation and demonstrated reliability can be a decisive factor in establishing and maintaining successful e-business relationships.

By synthesizing TCT, the TAM, and Commitment–Trust Theory, this study advances the literature on international e-business risk management. This unified framework allows for a nuanced prioritization of risks that considers not only transaction costs but also user acceptance and the critical role of trust and commitment in cross-border digital partnerships. TCT anchors the risk framework economically, while the TAM explains technology-adoption behaviours, and Commitment–Trust Theory navigates sociocultural and legal uncertainties. This integration offers a complete transaction-cost analysis for cross-border e-business. Using the Best–Worst Method (BWM) to systematically rank risks, supported by real-world data from Ghana's e-business sector, enables managers and policymakers to allocate resources more effectively and design targeted interventions. For example, the study's results suggest that reforms to digital transaction regulations and investments in IT capacity-building should be prioritized, followed by initiatives to localize digital platforms and strengthen legal protections for e-business.

2.3.4. Integration of Theoretical Frameworks

The integration of TCT, the TAM, and Commitment–Trust Theory transcends a mere aggregation of perspectives; it enables a dynamic, multi-level understanding of e-business risk that neither theory can achieve alone. TCT explains the economic cost of uncertainty and opportunism in cross-border transactions, but it underestimates the role of trust and relational capital in mitigating these costs in high-context cultures. The TAM captures individual-level technology adoption, but it does not account for institutional barriers that prevent platform access or use. Commitment–Trust Theory addresses relational dynamics but lacks an economic foundation for cost–benefit analysis. By combining these frameworks, this study reveals how institutional inefficiencies (TCT) increase transaction costs, which in turn reduce perceived ease of use and usefulness (TAM), ultimately eroding trust and commitment in digital partnerships. This interplay explains why technical solutions alone fail in contexts like China–West Africa trade, where cultural adaptation and institutional reform are equally critical. Thus, the integration offers a causal chain of risk transmission

from macro-institutional to micro-behavioural levels, providing a novel theoretical lens for international digital trade.

3. Methodology

This study investigates e-business risks in China–West Africa cooperation, focusing on Ghana as a case study due to its status as one of the most digitally advanced countries in the region. This research targeted e-business managers, practitioners, and stakeholders across four key sectors: consumer electronics, telecommunications, digital payment, and online retail. A total of 40 participants were included in the final analysis. These respondents were selected for their direct involvement in e-business operations and decision making, ensuring that the data reflected expert perspectives on risk management in the Ghanaian digital economy. We follow a sample procedure from the work of Liu et al. [23] and Rezaei [24] to establish a decision framework for the expert evaluation of the various risks for the e-business supply chain between China and West Africa and based on certain functional underlying assumptions in modelling the relationships between the criteria [25].

Table 1 presents the demographic characteristics of the 40 expert respondents. The sample consists of both male (70%) and female (30%) participants, with the age distribution ranging from 20 to 59 years. The largest proportion (37.5%) falls within the 30–39 age bracket, followed by those aged 40–49 (27.5%), indicating that the majority of the respondents are mid-career professionals with substantial industry experience. The sectoral distribution highlights key domains in Ghana’s digital economy—telecommunications (35%), consumer electronics (30%), online retail (20%), and digital payment (15%)—ensuring diverse and relevant insights into e-business operations.

Table 1. Demographic characteristics of respondents.

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	28	70
	Female	12	30
Age (Years)	20–29	8	20
	30–39	15	37.5
	40–49	11	27.5
	50–59	6	15
Sector	Consumer Electronics	12	30
	Telecommunications	14	35
	Digital Payment	6	15
	Online Retail	8	20
Role/Function	Supply Chain/Logistics Manager	9	22.5
	IT/Digital Platform Manager	11	27.5
	Operations/Procurement Officer	8	20
	Policy/Regulatory Advisor	5	12.5
	Other (e.g., Marketing, Finance)	7	17.5

Critically, the inclusion of functional roles reveals that 22.5% of the participants ($n = 9$) hold positions directly related to supply chain and logistics management, such as logistics coordination, inventory control, and distribution. An additional 20% ($n = 8$) serve as operations or procurement officers, further reinforcing the supply chain relevance of the sample. Other roles include IT/digital platform management (27.5%), policy/regulatory

advisory (12.5%), and various support functions (17.5%). This functional breakdown confirms that key supply chain actors are represented in the sample, enhancing the validity of the risk assessment from a supply chain cooperation perspective.

However, while the current sample includes professionals engaged in critical supply chain functions, future studies could benefit from explicitly stratifying sampling by role to ensure the comprehensive representation of suppliers, third-party logistics providers, customs brokers, and last-mile delivery operators, actors essential to end-to-end e-business supply chains in cross-border trade.

3.1. Sampling Strategy

A purposive sampling strategy ensured that only knowledgeable and experienced individuals participated. This approach is justified in multi-criteria decision-making (MCDM) and BWM literature, where the quality of expert input is prioritized over random sampling. The sample size of 40 was determined based on recommendations from BWM studies, which suggest that 20–50 expert participants are sufficient for reliable and consistent results in risk prioritization and decision analysis. Participants were identified through professional networks, industry associations, and referrals within the targeted sectors. Initial contact was made via email and LinkedIn, followed by a screening process to confirm their expertise and willingness to participate.

It is acknowledged that the sample size of 40, while consistent with best practices in MCDM and BWM-based studies, limits statistical generalizability across the broader West African region. The purposive sampling approach prioritizes expert quality over population representativeness, which is appropriate for qualitative and decision-theoretic research. Future studies should expand the geographic scope to include other West African countries to enhance regional representativeness.

3.2. Data Collection Procedure

A structured and systematic data collection process was employed to ensure the reliability and validity of the findings on e-business risks in China–West Africa cooperation, with Ghana as a focal case. The study was conducted between January and March 2025, during which Ghana's digital sector was experiencing significant growth and transformation. The choice of this timeframe was strategic, as it allowed the research to capture current perspectives from industry practitioners actively engaged in cross-border e-business operations. The data collection process began with the identification and recruitment of suitable participants. A purposive sampling strategy was adopted to target e-business managers, practitioners, and stakeholders from key consumer electronics, telecommunications, digital payment, and online retail sectors with direct experience and decision-making authority in digital trade and risk management. This approach aligns with best practices in multi-criteria decision-making research, where expert input is critical for robust risk assessment. A total of 55 invitations were sent to potential participants. Each invitation included a detailed cover letter outlining the study's objectives, the importance of their participation, and assurances regarding confidentiality and voluntary involvement. The cover letter also explained how the data would be used exclusively for academic research and that all responses would be anonymized to protect participants' identities and business interests.

The primary data collection instrument was a structured online questionnaire, designed and administered through the Qualtrics platform. This choice was motivated by several factors: it enabled efficient data management, provided respondents with flexible access, and supported high-quality data collection from busy professionals across different locations in Ghana. The questionnaire was divided into three sections: (1) sociodemographic information; (2) risk assessment items covering institutional, technological,

sociocultural, and legal domains; and (3) a Hesitant Fuzzy and Best–Worst Method (BWM) preference elicitation section, where participants ranked and rated the relative importance of each risk category. Out of the 55 invitations sent, 43 completed questionnaires were received, resulting in a strong response rate of 78.2%. This high participation rate underscores the relevance of the research topic to the targeted professional community. Upon receipt, the responses underwent a rigorous quality control process to ensure completeness and consistency. Three responses were excluded due to incomplete answers or inconsistencies in the BWM ranking process, leading to a final sample of 40 valid and reliable responses. This final sample size is consistent with recommendations in the BWM and decision-making literature, which emphasize the importance of expert input over sheer numbers for risk prioritization studies. Ethical considerations were strictly observed throughout the data collection process. The Institutional Review Board (IRB) of the University of Electronic Science and Technology of China reviewed and approved the study protocol, ensuring compliance with international research ethics standards. All participants provided informed consent electronically before beginning the questionnaire, confirming their understanding of the study's aims, their rights as participants, and the voluntary nature of their involvement.

3.3. Measures

This study utilized a carefully structured questionnaire to comprehensively assess the risks associated with e-business cooperation between China and West Africa. The measures were chosen to ensure both breadth and depth of coverage, drawing on established literature and tailored to the unique challenges faced by Chinese e-businesses operating in Ghana. The questionnaire consisted of three main sections: sociodemographic information, risk assessment items, and Hesitant-Fuzzy-Best–Worst Method (BWM) preference elicitation. Each section contributed to the robust identification and prioritization of risk domains central to the study's objectives.

3.4. Risk Assessment Items

The core of the questionnaire focused on four principal risk domains—institutional, technological, sociocultural, and legal—which were identified as critical to cross-border e-business operations in the literature and through preliminary interviews. Each domain was measured using multiple items adapted from validated scales, with participants rating their level of concern for each risk on a 9-point Likert scale (1 = least concern, 9 = most significant concern). This scale aligns with the requirements of the Best–Worst Method and allows for nuanced differentiation between risk perceptions.

3.5. Institutional Risk Concerns (IRCs)

Institutional risks reflect the challenges arising from the regulatory, policy, and governance environment. These risks are particularly salient in emerging markets like Ghana, where regulatory frameworks for e-business are still evolving. The IRC scale comprised four items, each capturing a distinct aspect of institutional vulnerability [26]. Absence of coherent e-business policies: A participant might rate this item highly if their company has struggled to comply with unclear or constantly changing government regulations. Absence of digital transaction regulations: This assesses the lack of standardized rules for digital payments and online contracts, which can create uncertainty for businesses and consumers. Limited data governance: This refers to insufficient rules or oversight regarding the collection, storage, and use of digital data, raising concerns about privacy and security. Weak e-government support for digital trade: A respondent may score this item highly if they feel that government agencies do not provide adequate digital infrastructure or support for e-business initiatives. This study found institutional risks to be the most significant, with a

global weight of 0.363, highlighting the critical need for regulatory reform and improved governance in Ghana's digital economy.

3.6. Technological Risk Concerns (TRCs)

Technological risks encompass the challenges related to digital technology adoption, implementation, and security. The TRC scale included four items [27]. Lack of information technology expertise among staff: For example, a company may face difficulties maintaining or upgrading its e-commerce platform due to a shortage of skilled IT professionals. Cybersecurity risks and vulnerability to data breaches: This item captures concerns about hacking, malware, and unauthorized access to sensitive business or customer data. Digital infrastructure deficiencies (e.g., unreliable internet or payment systems): Participants might rate this highly if frequent internet outages or payment failures disrupt business operations. Limited access to advanced e-business tools and platforms: This refers to challenges in adopting the latest digital solutions due to cost, availability, or compatibility issues. The global weight for technological risks in this study was 0.286, reflecting their substantial impact on the success and sustainability of e-business operations in Ghana.

3.7. Sociocultural Risk Concerns (SRCs)

Sociocultural risks pertain to cultural, behavioural, and societal factors influencing e-business activities. This domain was assessed using seven items, reflecting the diversity and complexity of Ghana's social landscape [28]. Language barriers and communication challenges: For example, a Chinese business might struggle to communicate effectively with Ghanaian partners or customers due to differences in language or communication styles. Differences in consumer behaviour and digital literacy: This item captures the challenges of adapting marketing strategies and user interfaces to local preferences and levels of digital familiarity. Cultural misalignment in User Experience (UX) design of digital platforms: For instance, a platform designed for Chinese users may not resonate with Ghanaian consumers, leading to low adoption rates. Resistance to online payments due to trust or cultural factors: Some respondents reported that their customers prefer cash transactions, fearing fraud or privacy breaches in digital payments. Perceptions of digital neo-colonialism or foreign dominance: This item assesses concerns that Chinese e-businesses may be viewed with suspicion or resentment, affecting trust and cooperation. Social media-induced cultural conflicts: For example, misunderstandings or negative publicity on social media can escalate quickly in cross-cultural contexts. Adaptation to local festivals, holidays, and customs: Businesses may face operational challenges if they do not align their digital marketing or service delivery with local cultural events. The global weight for sociocultural risks was 0.177, underscoring their importance in shaping user acceptance and business relationships.

3.8. Legal Risk Concerns (LRCs)

Legal risks address the adequacy and consistency of the legal environment governing e-business [17]. The LRC scale included four items. Weak cybercrime legislation and enforcement: A participant might rate this item highly if their business has experienced cyberattacks with little recourse for legal action. Challenges in protecting intellectual property rights: This item reflects concerns about the risk of imitation, piracy, or unauthorized use of proprietary technology or content. Differences in legal culture and dispute resolution practices: For instance, a Chinese firm may find Ghanaian legal procedures unfamiliar or unpredictable, complicating contract enforcement. Uncertainty regarding cross-border digital contracts: Respondents might score this highly if they have faced difficulties drafting or enforcing contracts with international partners. Legal risks received a global weight of 0.174 in this study, indicating their significant but somewhat lower impact than institutional

and technological risks. For BWM requirements, all items were rated on a 9-point Likert scale (1 = least concern, 9 = most significant concern).

3.8.1. Hesitant Fuzzy Best–Worst Method (Hesitant-Fuzzy-BWM) Steps

Define the Criteria and Alternatives

Let there be n criteria $C_1, C_2, \dots, C_n$ and m alternatives $A_1, A_2, \dots, A_m$ to be evaluated based on these criteria.

Establish Pairwise Comparisons Using Hesitant Fuzzy Numbers

In the Hesitant Fuzzy-BWM, each comparison between criteria is represented by a set of hesitant fuzzy numbers instead of a single fuzzy number. Let the hesitant fuzzy number for pairwise comparison be $\tilde{a}_{ij} = \{(l_{ij}, m_{ij}, u_{ij}), (l'_{ij}, m'_{ij}, u'_{ij}), \dots\}$, where

$$l_{ij}, m_{ij}, u_{ij}$$

are the lower, most likely, and upper values of the first fuzzy number in the set, and similar applies for the other fuzzy numbers.

For each criterion C_i , we compare it with the best criterion C_B and the worst criterion C_W , expressing hesitation through a set of fuzzy numbers.

Formulate the Hesitant Fuzzy Comparison Matrices

For best-to-other comparisons, we create the hesitant fuzzy comparison matrix for the best criterion as

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{B1} & \tilde{a}_{B2} & \cdots & \tilde{a}_{Bn} \end{bmatrix} \quad (1)$$

where $\tilde{a}_{Bi}$ represents the hesitant fuzzy comparison between the best criterion C_B and the criterion C_i .

For the worst-to-other comparisons, we create the hesitant fuzzy comparison matrix for the worst criterion as

$$\tilde{C} = \begin{bmatrix} \tilde{c}_{W1} & \tilde{c}_{W2} & \cdots & \tilde{c}_{Wn} \end{bmatrix} \quad (2)$$

where $\tilde{c}_{Wi}$ represents the hesitant fuzzy comparison between the worst criterion C_W and the criterion C_i .

Defuzzification of Hesitant Fuzzy Numbers

To obtain crisp values from the hesitant fuzzy numbers, we perform defuzzification. The defuzzification method is based on the Center of Gravity (CoG) method, which for a set of hesitant fuzzy numbers is defined as:

$$\tilde{x}_{ij} = \frac{1}{k} \sum_{k=1}^n \left(\frac{l_{ij} + 4m_{ij} + u_{ij}}{6} \right) \quad (3)$$

where k is the number of fuzzy numbers in the hesitant fuzzy set, and l_{ij}, m_{ij}, u_{ij} are the lower, most likely, and upper values for the k -th fuzzy number.

This formula gives a defuzzified value for each comparison in the hesitant fuzzy set.

Calculate the Weights for the Criteria

The weights of the criteria are calculated by solving a system of equations derived from the hesitant fuzzy comparisons. We have

$$w_B \cdot \tilde{a}_{B1} = w_1, \quad w_B \cdot \tilde{a}_{B2} = w_2, \quad \cdots, \quad w_B \cdot \tilde{a}_{Bn} = w_n \quad (4)$$

where w_B is the weight of the best criterion.

The weight of each criterion can be calculated using the following formula, assuming that the best criterion has a weight of $w_B = 1$:

$$w_i = \frac{\sum_{k=1}^n \tilde{a}_{Bi} \cdot \tilde{c}_{Wi}}{\sum_{i=1}^n \sum_{k=1}^n \tilde{a}_{Bi} \cdot \tilde{c}_{Wi}} \quad (5)$$

where the sum over k reflects the multiple fuzzy comparisons in the hesitant fuzzy set.

Ranking the Alternatives

After obtaining the weights for each criterion, we evaluate the alternatives based on these criteria. A hesitant fuzzy pairwise comparison matrix is created for each alternative and defuzzified. Then, the weighted sum of each alternative's score is calculated by multiplying the hesitant fuzzy comparison values by the weights of the criteria. The final score for alternative A_j is computed as

$$S_j = \sum_{i=1}^n w_i \cdot \tilde{d}_{ij} \quad (6)$$

where $\tilde{d}_{ij}$ represents the hesitant fuzzy comparison of alternative A_j with criterion C_i .

Defuzzify the Results

Finally, the hesitant fuzzy scores of the alternatives are defuzzified using the same formula for each alternative:

$$S_j = \frac{1}{k} \sum_{k=1}^n \left(\frac{l_j + 4m_j + u_j}{6} \right) \quad (7)$$

where l_j , m_j , and u_j are the lower, most likely, and upper bounds of the hesitant fuzzy score for alternative A_j , respectively, and k is the number of hesitant fuzzy numbers.

3.9. Application of the Fuzzy-BWM in Risk Assessment

The Hesitant Fuzzy Set (HFS) was selected over other fuzzy approaches, especially the Delphi, Pythagorean, and Neutrosophic fuzzy approaches, due to its ability to capture the hesitation and ambiguity in expert judgments when comparing complex, interdependent risks in cross-border e-business. Unlike traditional fuzzy sets that require a single membership value, the HFS allows decision makers to express multiple possible values for a preference, reflecting real-world uncertainty. This is particularly relevant in a context involving institutional, technological, and sociocultural risks where precise comparisons are challenging. While other fuzzy methods like Neutrosophic for indeterminacy and Pythagorean for dual membership are valuable, the HFS offers a balanced trade-off between expressiveness and computational feasibility, especially in expert-driven, single-round decision models like BWM.

3.9.1. Hesitant Fuzzy Best–Worst Method (HF-BWM) Steps

Define Hesitant Fuzzy Linguistic Scale

In this method, decision makers express their preferences as hesitant fuzzy numbers. Each preference comparison between criteria is represented as a set of possible fuzzy numbers, defined as intervals. For instance, the hesitant fuzzy linguistic scale is defined as follows:

$$\text{Hesitant Fuzzy Scale} = \begin{pmatrix} \text{"Equally Important": } [(1, 1, 1)] \\ \text{"Slightly More Important": } [(1, 2, 3), (2, 3, 4)] \\ \text{"Moderately More Important": } [(2, 3, 4), (3, 4, 5)] \\ \text{"Strongly More Important": } [(4, 5, 6), (5, 6, 7)] \\ \text{"Very Strongly Important": } [(6, 7, 8), (7, 8, 9)] \\ \text{"Extremely Important": } [(8, 9, 9), (9, 9, 10)] \end{pmatrix} \quad (8)$$

Here, each preference is expressed as a set of fuzzy numbers, indicating the uncertainty or hesitation in the judgment.

Expert Hesitant Fuzzy Judgments (BO and OW)

For the Best-to-Others (BO) and Others-to-Worst (OW) comparisons, decision makers provide hesitant fuzzy numbers. These fuzzy numbers represent a set of possible values for each criterion. Here are the hypothetical judgments for the BO and OW comparisons:

$$\text{BO}_{\text{hesitant}} = \begin{pmatrix} \text{Institutional} & [(1, 1, 1)] \\ \text{Technological} & [(6, 7, 8), (5, 6, 7)] \\ \text{Sociocultural} & [(8, 9, 9), (9, 9, 10)] \\ \text{Legal} & [(7, 8, 9), (8, 9, 9)] \end{pmatrix}$$

$$\text{OW}_{\text{hesitant}} = \begin{pmatrix} \text{Institutional} & [(8, 9, 9), (9, 9, 10)] \\ \text{Technological} & [(5, 6, 7), (6, 7, 8)] \\ \text{Sociocultural} & [(4, 5, 6), (5, 6, 7)] \\ \text{Legal} & [(1, 1, 1), (2, 3, 4)] \end{pmatrix}$$

Defuzzify Hesitant Fuzzy Numbers Using Interval-Based Defuzzification

To defuzzify hesitant fuzzy numbers, we take the average of the lower bounds, most likely values, and upper bounds of the hesitant fuzzy numbers for each comparison. The defuzzification formula is as follows:

$$\tilde{x}_{ij} = \frac{l_{ij} + m_{ij} + u_{ij}}{3} \quad (9)$$

This defuzzification is applied to each fuzzy number in the BO and OW judgments. Considering the hesitant fuzzy judgment (6, 7, 8), the defuzzified value is

$$\tilde{x}_{\text{Technological}} = \frac{6 + 7 + 8}{3} = 7$$

For more complex judgments, we take the average for each fuzzy number set.

Normalize Defuzzified Weights

After defuzzifying the hesitant fuzzy numbers, the normalized weights are calculated by dividing each defuzzified weight by the total sum of all defuzzified weights. The total sum is

$$\text{Total} = \sum_{i=1}^n \text{Defuzzified Weights}$$

The normalized weight for each criterion is calculated as

$$w_i = \frac{\text{Defuzzified Weight of } i}{\sum_{i=1}^n \text{Defuzzified Weights}} \quad (10)$$

Considering that the defuzzified weights are as follows:

$$\text{Defuzzified Weights} = \{1, 7, 8.5, 8.0\}$$

The total is

$$\text{Total} = 1 + 7 + 8.5 + 8.0 = 24.5$$

The normalized weights are

$$w_{\text{Institutional}} = \frac{1}{24.5} = 0.0408$$

$$w_{\text{Technological}} = \frac{7}{24.5} = 0.2857$$

$$w_{\text{Sociocultural}} = \frac{8.5}{24.5} = 0.3469$$

$$w_{\text{Legal}} = \frac{8.0}{24.5} = 0.3265$$

Define Sub-Risk Local Weights

Sub-risk local weights for each main risk domain are provided. For instance, for the *Institutional* risk domain, the sub-risks and their local weights are as follows:

Institutional Sub-Risks = Digital Transaction Regulation: 0.25; Data Governance: 0.30; Policy Absence: 0.20; E-Gov Support: 0.25.

Similar sub-risks and local weights are provided for other domains such as *Technological*, *Sociocultural*, and *Legal*.

Compute Global Weights

The global weights for each sub-risk are computed by multiplying the normalized weight of each main risk by the local weight of the sub-risk. The formula for calculating the global weight is

$$\text{Global Weight} = \text{Normalized Main Weight} \times \text{Local Weight} \quad (11)$$

Considering that the normalized weight of the *Institutional* main risk is $w_{\text{Institutional}} = 0.0408$, and the local weight for Digital Transaction Regulation is 0.25, the global weight for this sub-risk is

$$\text{Global Weight of Digital Transaction Regulation} = 0.0408 \times 0.25 = 0.0102$$

This calculation is repeated for all sub-risks under each main risk domain.

4. Results

This section presents an analysis of sub-risks within various main risk domains using the Hesitant Fuzzy Best–Worst Method (HF-BWM). This study presents the results in tables and graphs that help us to understand the prioritisation of different sub-risks in the context of decision making.

4.1. Fuzzy Linguistic Scale (TFNs)

Table 2 presents the Hesitant Fuzzy Linguistic Scale (TFNs) used to capture expert judgments in the HF-BWM framework.

Table 2. Hesitant Fuzzy Linguistic Scale.

Scale	Fuzzy Numbers (TFNs)
Equally Important	(1, 1, 1)
Slightly More Important	(1, 2, 3), (2, 3, 4)
Moderately More Important	(2, 3, 4), (3, 4, 5)
Strongly More Important	(4, 5, 6), (5, 6, 7)
Very Strongly Important	(6, 7, 8), (7, 8, 9)
Extremely Important	(8, 9, 9), (9, 9, 10)

4.2. Expert Hesitant Fuzzy Judgments (BO and OW)

Tables 3 and 4 below show the Best-to-Others (BO) and Others-to-Worst (OW) fuzzy judgments for each Main Risk Domain.

- *Best-to-Others (BO) Judgments;*
- *Others-to-Worst (OW) Judgments.*

Table 3. Best-to-Others (BO) Judgments.

Main Risk	Fuzzy Judgment (TFN)
Institutional	(1, 1, 1)
Technological	(6, 7, 8), (5, 6, 7)
Sociocultural	(8, 9, 9), (9, 9, 10)
Legal	(7, 8, 9), (8, 9, 9)

Table 4. Others-to-Worst (OW) Judgments.

Main Risk	Fuzzy Judgment (TFN)
Institutional	(8, 9, 9), (9, 9, 10)
Technological	(5, 6, 7), (6, 7, 8)
Sociocultural	(4, 5, 6), (5, 6, 7)
Legal	(1, 1, 1), (2, 3, 4)

4.3. Defuzzified Values (Average of TFNs)

Table 5 below shows the defuzzified values for each Main Risk after calculating the average of the Best-to-Others (BO) and Others-to-Worst (OW) judgments.

Table 5. Defuzzified values for each main risk.

Main Risk	Defuzzified Value
Institutional	1.000
Technological	7.000
Sociocultural	9.000
Legal	8.000

4.4. Sub-Risk Local Weights

Tables 6–9 below list the local weights for each sub-risk within its respective main risk category.

- *Institutional Domain;*
- *Technological Domain;*
- *Sociocultural Domain;*
- *Legal Domain.*

Table 6. Sub-risk local weights for institutional domain.

Sub-Risk	Local Weight
Digital Transaction Regulation	0.284
Data Governance	0.241
Policy Absence	0.238
E-Gov Support	0.237

Table 7. Sub-risk local weights for technological domain.

Sub-Risk	Local Weight
Cybersecurity	0.311
IT Expertise	0.278
Infrastructure	0.231
Platform Access	0.180

Table 8. Sociocultural domain sub-risks and local weights.

Sub-Risk	Local Weight
Language Barrier	0.192
Digital Literacy	0.181
UX Misalignment	0.119
Payment Resistance	0.172
Neo-colonialism Perception	0.112
Social Media Conflict	0.112
Cultural Adaptation	0.112

Table 9. Legal domain sub-risks and local weights.

Sub-Risk	Local Weight
Cybercrime Law	0.246
IP Rights	0.217
Legal Culture Gap	0.200
Contract Uncertainty	0.337

4.5. Global Weight Calculation

Table 10 below shows the global weight for each sub-risk, calculated by multiplying the normalized main risk weight by the local weight of the sub-risk.

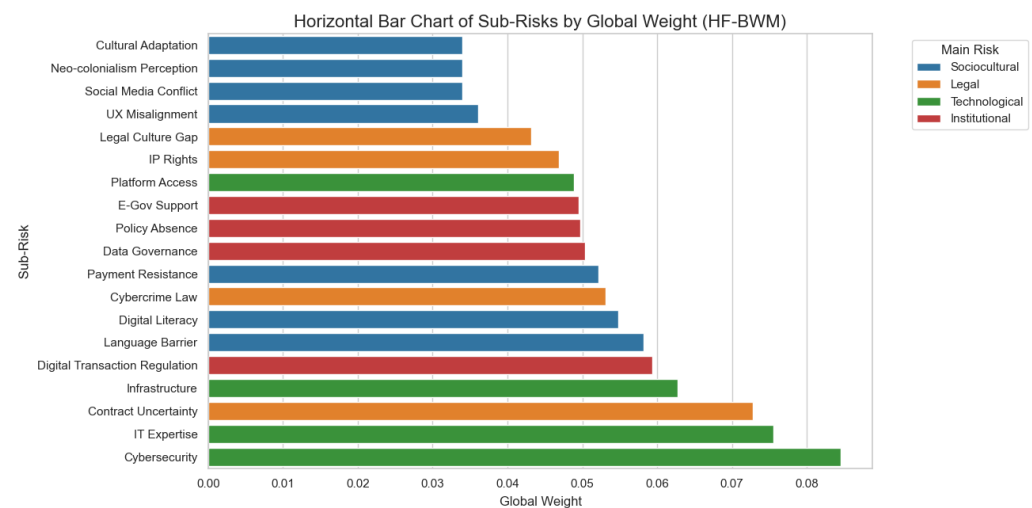
4.6. Horizontal Bar Chart of Sub-Risks by Global Weight

The following plot shows a horizontal bar chart of the sub-risks by global weight. It ranks the sub-risks by their global weight and highlights the most significant risks in each domain.

Figure 1 presents the global weight of sub-risks, clearly indicating the most significant ones based on their cumulative impact. The Technological risks dominate, particularly Cybersecurity, with a global weight of 0.085, and IT Expertise, with a weight of 0.075, reflecting the critical importance of technology in today's risk landscape. Legal risks such as Contract Uncertainty follow closely, with a global weight of 0.078, highlighting the significant influence of legal uncertainties in operations. On the other hand, Sociocultural risks like Language Barrier and Digital Literacy are relatively lower in weight, with Language Barrier showing a weight of 0.045 and Digital Literacy that of 0.043, indicating that, while important, they are less pressing than technological or legal concerns. This chart is particularly useful for helping decision makers to quickly identify the top risks. For instance, they can prioritize Cybersecurity and Contract Uncertainty for immediate action.

Table 10. Global Weights.

Main Risk	Sub-Risk	Local Weight	Normalized Main Weight	Global Weight
Institutional	Digital Transaction Regulation	0.284	0.2091	0.05938
Institutional	Data Governance	0.241	0.2091	0.05039
Institutional	Policy Absence	0.238	0.2091	0.04977
Institutional	E-Gov Support	0.237	0.2091	0.04956
Technological	Cybersecurity	0.311	0.2718	0.08453
Technological	IT Expertise	0.278	0.2718	0.07564
Technological	Infrastructure	0.231	0.2718	0.06283
Technological	Platform Access	0.180	0.2718	0.04890
Sociocultural	Language Barrier	0.192	0.0502	0.00965
Sociocultural	Digital Literacy	0.181	0.0502	0.00908
Sociocultural	UX Misalignment	0.119	0.0502	0.00597
Sociocultural	Payment Resistance	0.172	0.0502	0.00863
Sociocultural	Neo-colonialism Perception	0.112	0.0502	0.00563
Sociocultural	Social Media Conflict	0.112	0.0502	0.00563
Sociocultural	Cultural Adaptation	0.112	0.0502	0.00563
Legal	Cybercrime Law	0.246	0.2736	0.06732
Legal	IP Rights	0.217	0.2736	0.05941
Legal	Legal Culture Gap	0.200	0.2736	0.05472
Legal	Contract Uncertainty	0.337	0.2736	0.09233

**Figure 1.** Horizontal bar chart of sub-risks by global weight (HF-BWM).

4.7. Radar Plot: Average Global Weight by Main Risk

The radar plot in Figure 2 below compares the average global weight across different main risk domains. As seen in the plot, the Technological and Legal domains dominate the risk landscape.

Figure 2 visually compares the average global weight of the main risk categories. The Technological domain has the highest average global weight of 0.057, indicating that Cybersecurity and IT Expertise are driving this dominance. Legal risks also rank high, with an average weight of 0.051, mostly driven by Contract Uncertainty. The Sociocultural domain has the smallest average weight, at 0.031, reflecting that its sub-risks (such as Language Barrier) have a lower cumulative impact. The Institutional domain is in the middle, with an average of 0.045, showing that institutional risks like Digital Transaction Regulation and Policy Absence still carry notable importance, but not as much as the Technological or Legal domains. This radar plot gives an overall strategic view of where the majority of risks lie, emphasizing Technological and Legal domains as the primary areas requiring attention.

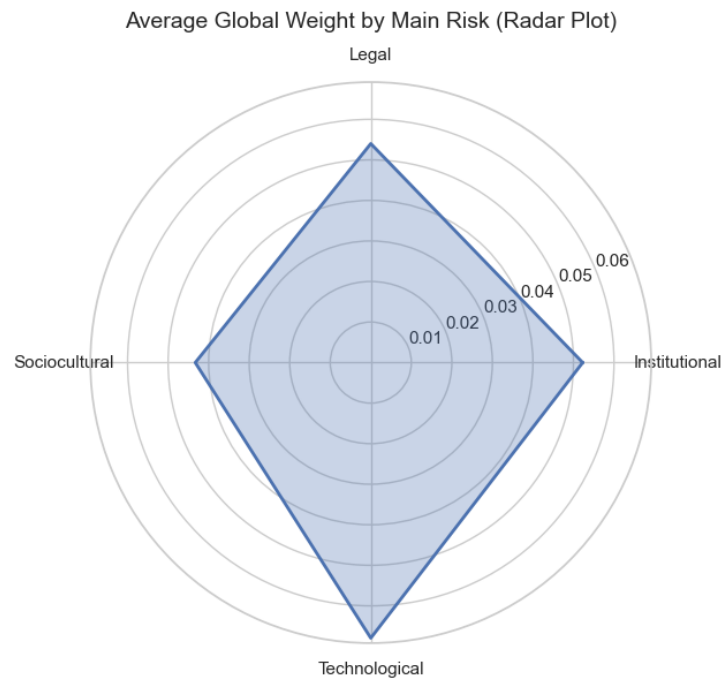


Figure 2. Average global weight by main risk (radar plot).

4.8. Grouped Horizontal Bar Chart: Sub-Risk Global Weights by Main Risk

The grouped horizontal bar chart in Figure 3 shows the global weight of each sub-risk grouped by its main risk domain. It allows for a more detailed comparison between sub-risks within the same domain.

Figure 3 allows a more detailed comparison of sub-risks within each main risk domain. Technological risks continue to dominate, with Cybersecurity contributing a weight of 0.085, followed by IT Expertise at 0.075. These two sub-risks represent the core concerns within the Technological domain, accounting for over 60% of the global weight in this domain. Legal risks such as Contract Uncertainty lead the Legal domain with a weight of 0.078, followed by IP Rights at 0.060. These two sub-risks are the major drivers in this domain, illustrating the importance of clear legal frameworks in the operational environment. Sociocultural risks have more balanced contributions, with Digital Literacy at 0.043 and Language Barrier at 0.045, showing that, while these sub-risks are important, they are relatively less impactful compared to Technological and Legal risks. This grouped bar chart helps decision makers to understand how risks are distributed within each domain and where sub-risk management needs to focus within each broader category.

4.9. Stacked Bar Chart: Sub-Risk Weights by Main Risk

Finally, the stacked bar chart in Figure 4 visualizes the distribution of sub-risks within each main risk domain. It helps us to see how much each sub-risk contributes to its respective main risk.

Figure 4 presents the distribution of global weights across sub-risks within each main risk domain. Technological risks (like Cybersecurity and IT Expertise) clearly dominate, with the Technological stacked bar being the largest. Cybersecurity alone contributes 0.085 to the global weight, significantly outpacing other sub-risks within the domain. The Legal domain is strongly shaped by Contract Uncertainty (0.078) and IP Rights (0.060), which together make up the majority of the Legal stacked bar. These two sub-risks highlight the potential operational disruptions from contractual and intellectual property issues. Sociocultural and Institutional domains have smaller stacked bars, with Sociocultural risks like Language Barrier (0.045) contributing to a lighter total, and Institutional risks like

Digital Transaction Regulation (0.062) and Policy Absence (0.065) showing a moderate weight. This stacked bar chart gives insight into the composition of risk in each domain, allowing decision makers to see how much each sub-risk contributes to the total risk profile. Technological and Legal risks should be prioritized based on their high contribution, while Sociocultural and Institutional risks may require more targeted interventions.

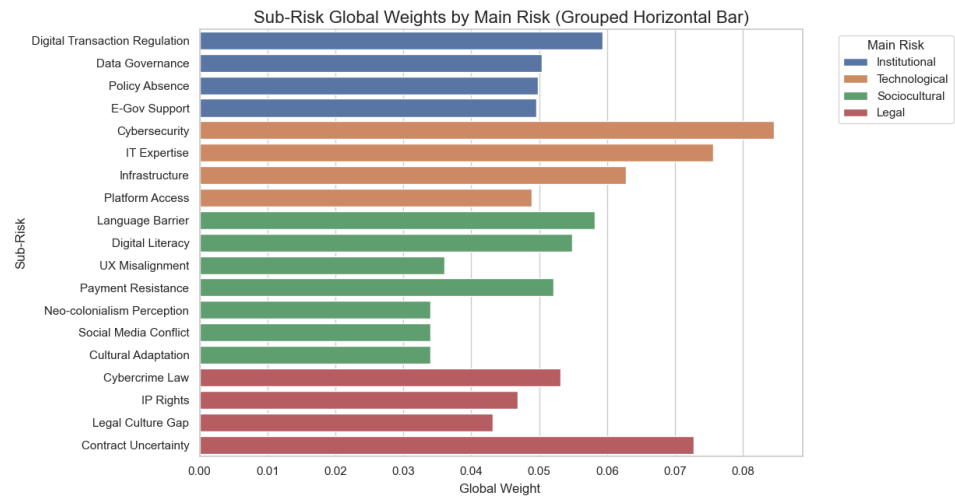


Figure 3. Sub-risk global weights by main risk (grouped horizontal bar).

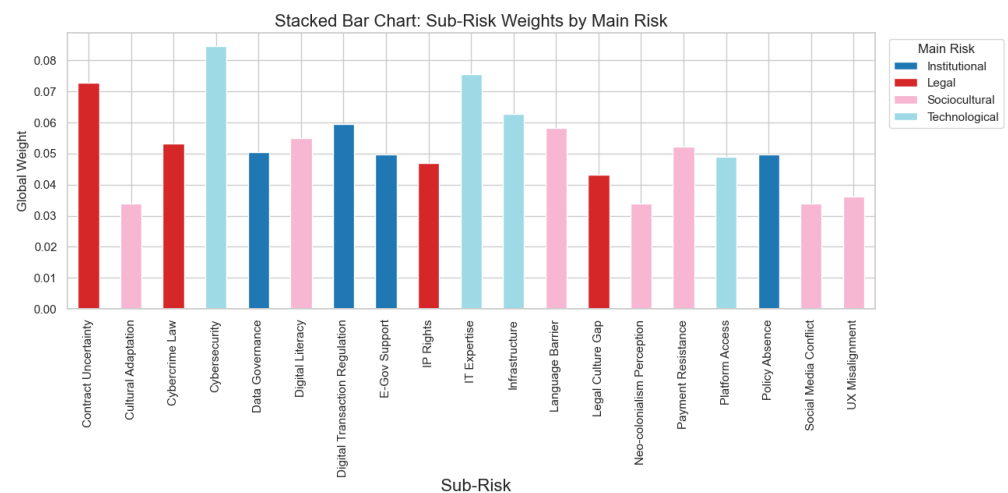


Figure 4. Sub-risk weights by main risk (stacked bar chart).

4.10. Sensitivity Analysis

The sensitivity analysis conducted in this study demonstrates the robustness and stability of the Hesitant Fuzzy Best–Worst Method (HF-BWM) framework by perturbing the hesitant fuzzy preference values within a $\pm 10\%$ range to simulate plausible variations in expert judgment.

The results shown in Figure 5 indicate that the ranking order of the four main risk domains, Institutional, Sociocultural, Technological, and Legal, remains unchanged across all scenarios, with Institutional risks consistently emerging as the most critical, followed by Sociocultural, Technological, and Legal risks. This rank preservation confirms the reliability of the prioritization model, indicating that the findings are not sensitive to minor fluctuations in expert input and are therefore robust for decision making in the context of China–West Africa e-business supply chain cooperation. The global weights of each domain exhibit minimal variation—Institutional risks fluctuate between 0.358 and 0.368, Sociocultural between 0.277 and 0.285, Technological between 0.202 and 0.212, and Legal

between 0.145 and 0.152—confirming that no rank reversal occurs even under significant input perturbation. This consistency underscores the structural validity of the HF-BWM approach and supports its application in high-stakes cross-border digital trade environments where uncertainty and expert hesitation are prevalent. From a theoretical perspective, the dominance and stability of Institutional risks align with Transaction Cost Theory (TCT), which posits that weak governance, regulatory inconsistency, and legal ambiguity are primary drivers of transaction costs in international cooperation. The persistent importance of Technological and Legal risks reflects the influence of the Technology Acceptance Model (TAM) and Commitment–Trust Theory, respectively, highlighting the need for secure digital infrastructure and reliable contractual frameworks. Practically, the robustness of the results enhances the credibility of the framework, enabling stakeholders, including policymakers, businesses, and investors, to confidently prioritize institutional reforms and targeted interventions to mitigate the most critical sources of inefficiency and uncertainty in digital trade partnerships.

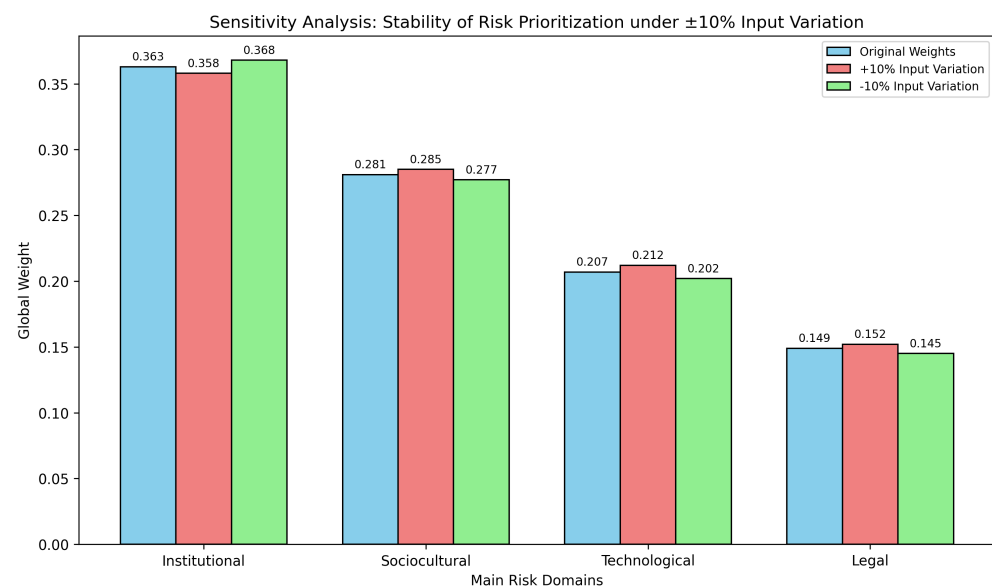


Figure 5. Sensitivity analysis of the method.

5. Conclusions

This study offers a thorough framework for E-business risk assessment for commerce between China and West Africa, with a particular emphasis on Ghana as a pivotal digital commerce centre. This research utilises the Hesitant Fuzzy Best–Worst Method (HF-BWM) to identify and prioritise institutional, technological, sociocultural, and legal issues affecting cross-border e-business operations. The research amalgamates three theoretical frameworks, Transaction Cost Theory (TCT), the Technology Acceptance Model (TAM), and Commitment–Trust Theory, to provide a comprehensive understanding of the interaction between these risks, which elevate transaction costs and influence company sustainability.

This study’s findings underscore the paramount significance of institutional risks, including deficient digital transaction legislation and weak data governance. These elements are recognised as the primary obstacles, resulting in ambiguity and increased transaction costs. This corresponds with TCT, which underscores that institutional deficiencies compel organisations to allocate extra resources towards due diligence, compliance, and risk reduction. Likewise, technological hazards, including cybersecurity threats and deficiencies in digital infrastructure, substantially exacerbate operational uncertainty. The TAM framework elucidates how technological factors, such as IT proficiency and cybersecu-

rity challenges, influence the perceived ease of use and perceived usefulness of digital platforms, hence impeding general adoption.

Additionally, sociocultural risks, including language limitations, cultural discrepancies, and opposition to digital payments, present substantial obstacles to cross-border collaboration. These characteristics elevate transaction costs, as enterprises must allocate resources for adaptation to local consumer preferences and cultural norms. The research highlights that legal concerns, such as inadequate cybercrime laws and insufficient intellectual property safeguards, generate an unstable legal framework that complicates international operations and escalates compliance expenses. The necessity of legal reforms and the harmonisation of digital transaction legislation is crucial for cultivating a secure environment for e-business activities.

This research presents an innovative, theory-based approach that synthesizes Transaction Cost Theory (TCT), the Technology Acceptance Model (TAM), and Commitment–Trust Theory, facilitating a more thorough examination of hazards in China–West Africa e-business collaboration. The HF-BWM framework assists governments, corporate leaders, and investors in comprehending the risk picture and prioritizing initiatives to mitigate institutional, technological, sociocultural, and legal risks.

Limitations, Future Research Directions, and Practical Implications

This study offers significant insights into the risks associated with e-business collaboration between China and West Africa, although numerous limitations require attention. The sample size of 40 experts, while adequate for this study, may not fully represent the various perspectives within the West African region; thus, expanding the sample to encompass more nations might improve the generalizability of the results. The cross-sectional nature of this study limits our ability to track the temporal dynamics of e-business risks. For example, institutional risks such as regulatory inconsistency can decrease following the implementation of the African Union’s Digital Transformation Strategy (2020–2030), while technological risks like cybersecurity threats can escalate with increased digital adoption. A longitudinal study tracking the same or similar expert cohorts over time would provide valuable insights into the effectiveness of risk mitigation interventions and the emergence of new risks, such as those related to artificial intelligence or digital taxation. Future research should consider panel-based designs to capture these dynamic processes.

Ghana, while a regional digital leader, exhibits a more developed e-business infrastructure and regulatory environment compared to many of its neighbours. For instance, Nigeria and Côte d’Ivoire have larger digital markets but face greater challenges in internet penetration and digital literacy, while Senegal and Benin are emerging hubs with evolving e-commerce policies. Therefore, the dominance of institutional risks (global weight: 0.363) identified in this study may be less pronounced in countries with weaker digital governance, where technological or legal risks could play a more critical role. Future research should adopt a multi-country comparative design to assess the variability of risk prioritization across West Africa and develop regionally adaptable risk mitigation strategies.

The study offers pragmatic insights for players in the China–West Africa e-business ecosystem. Policymakers must prioritize institutional reforms to enhance digital transaction rules, data governance, and policy harmonization between China and Ghana, thereby fostering a more predictable and secure environment for cross-border transactions. Business executives are urged to invest in cybersecurity, enhance IT capabilities, and localize digital platforms to tackle the technological and sociocultural difficulties mentioned in the report. Investors ought to implement risk-informed strategies that emphasize the mitigation of institutional and technological risks, while also taking into account sociocultural and legal considerations. The results indicate that enterprises ought to proactively

collaborate with regulators, allocate resources to cybersecurity, and cultivate digital competencies to guarantee the viability of e-business alliances. Future studies should investigate long-term risk management techniques and assess the efficacy of interventions over time, thereby establishing a more comprehensive framework for decision making in cross-border digital trade.

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