FACTORS AFFECTING THE ADOPTION LEVEL OF BLOCKCHAIN TECHNOLOGY TO DEVELOP THE AGRICULTURAL SUPPLY CHAIN

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Abstract. *Based on applying structural equation modeling (SEM), this study analyzes the factors affecting the adoption level of blockchain technology to develop the agricultural supply chain. The study applies qualitative and quantitative research methods to analyze this issue. The quantitative survey is conducted with a sample of 356 organizations/individuals participating in the pork supply chain in Hue City; the sample is selected based on a simple random method. Research results indicate that: First, about 47.3% of supply chain stakeholders are willing to invest 1% to 5% of revenue in blockchain development, and 46% expect to help increase the rate of return from 5% to 20%. Second, blockchain adoption intention (INT) is most influenced by the technology condition (TECH) and inter-organizational condition (INTER). The adoption level (AL) is directly and indirectly affected by four different factors in the model. Third, the industry characteristic has a moderating effect on the relationship between intent and application level. Finally, different stakeholder groups show different levels of readiness for blockchain adoption.*

Keywords: *Adoption level, blockchain, agricultural supply chain.*

CÁC NHÂN TỐ ẢNH HƯỞNG ĐẾN MỨC ĐỘ ỨNG DỤNG CÔNG NGHỆ BLOCKCHAIN NHẰM PHÁT TRIỂN CHUỖI CUNG ỨNG NÔNG NGHIỆP

Tóm tắt. *Trên cơ sở vận dụng mô hình phương trình cấu trúc (SEM), nghiên cứu này được thực hiện nhằm phân tích các nhân tố ảnh hưởng đến mức độ ứng dụng blockchain vào việc phát triển chuỗi cung nông nghiệp. Để phân tích vấn đề này, nghiên cứu áp dụng cả hai phương pháp nghiên cứu định tính và định lượng. Trong đó, bước khảo sát định lượng được thực hiện với mẫu điều tra là 356 đơn vị tổ chức/cá nhân tham gia vào chuỗi cung ứng thịt lợn tại thành phố Huế, mẫu được chọn dựa trên phương pháp ngẫu nhiên đơn giản. Kết quả nghiên cứu chỉ ra rằng: Thứ nhất, khoảng 47,3% thành viên trong chuỗi cung ứng sẵn sàng đầu tư từ 1% đến 5% doanh thu cho việc phát triển blockchain và 46% kỳ vọng sẽ giúp tăng tỷ lệ lợi nhuận từ 5% đến 20%. Thứ hai, ý định ứng dụng blockchain (INT) chịu tác động lớn nhất bởi điều kiện công nghệ (TECH) and điều kiện liên tổ chức (INTER). Mức độ ứng dụng (AL) chịu tác động trực tiếp lẫn gián tiếp từ bốn nhóm biến trong mô hình. Thứ ba, đặc điểm ngành (IC) có tác động điều tiết đến mối quan hệ giữa ý định và mức độ ứng dụng. Cuối cùng, Các nhóm thành viên trong chuỗi cung ứng có sự khác biệt rõ rệt trong đánh giá về mức độ sẵn sàng ứng dụng blockchain.*

Từ khóa: *Mức độ ứng dụng, blockchain, chuỗi cung ứng nông nghiệp.*

1. Introduction

Adopting blockchain technology to supply chain management activities in general, and developing agricultural supply chains in particular, is having fierce debates. On the one hand, blockchain brings excellent benefits, such as gradually eliminating third-party intermediaries, increasing transparency, increasing traceability, simplifying administrative procedures, and reducing operating costs in the supply chain. However, on the other hand, the low willingness to share information from stakeholders, high investment and operating costs, poor quality of human resources, and inadequate legal foundations make blockchain an unfeasible solution for developing agricultural supply chains.

In the current situation, when agricultural supply chains face more and more unsustainable issues, the requirement of finding solutions for adopting blockchain technology is getting more and more attention. Indeed, according to statistics from the Food Safety Department, there are about 172,000 cases of food poisoning on average in Vietnam every year, with more than 5,000 victims and 28 deaths. Foods with unknown origins cause the majority of poisoning cases, so it is difficult to trace the source of the harm (Food Safety Authority, 2020). In addition, according to the Ministry of Agriculture and Rural Development assessment, despite the benefits of Vietnam - EU free trade agreement (EVFTA), more than 90% of Vietnamese agricultural products do not meet the penetrating standards for this market. This is mainly due to the need for more practical tools for traceability, ensuring elements of social responsibility, monitoring compliance with environmental standards, and green consumption. These realities imply that new technologies like blockchain are urgently needed to develop sustainable agricultural supply chains.

Regarding the academic aspect, along with the increasing popularity of blockchain, research on the adoption of blockchain to agricultural supply chains has also attracted much attention. Most studies use qualitative research tools to assess the benefits and barriers to applying blockchain technology (Yuan et al., 2020). In addition, several quantitative research models have also been built to analyze the relationship between blockchain adoption and the sustainable improvements of agricultural supply chains (Wu et al., 2021). However, aspects related to the compatibility of blockchain technology with existing technologies in the current supply chain have barely been considered. Similarly, the financial readiness, technological readiness, and readiness on human knowledge of the stakeholders in the supply chain have yet to be thoroughly evaluated to clarify the feasibility of blockchain applications. Also, the current literature only considers blockchain adoption “intention”; almost few studies help to measure the “adoption level.” Further, the moderating factors affecting the relationship between enablers and the application level have been largely ignored.

In this study, the case of the pork supply chain in Hue, Vietnam, is selected for two main reasons: First, the pork supply chains have a high potential for blockchain technology adoption. Indeed, the pork supply chains include many stakeholders (pig breeders/fatteners, feed industry, livestock dealers, processors/ slaughterhouses, retailers, and customers). Also, the pork supply chain has a low level of interoperability among all stakeholders (compared to the supply chain of automobiles, electronics, and textiles). Thus, with its high complexity and high demand for information control, adopting blockchain technology in the pork supply chain is urgent. In fact, in agricultural fields, the pork supply chain has the most application case of the blockchain worldwide (Devin & Richards, 2018). Therefore, this case is a suitable, highly representative, and generalizable case study for agricultural supply chains. Second, most current research on blockchain technology applications is conducted in developed countries such as the US, Norway, and France. Research in a developing country like Vietnam helps to provide new and high reference valued results.

The results from this study contribute to outlining a new conceptual framework to analyze the factors affecting the adoption level of blockchain in the development of a sustainable pork supply chain. This result helps to extend the existing technology-organization-environment (TOE) theoretical framework. The new theoretical framework also contributes to examining the influence of industry characteristics on the relationship between stakeholder readiness and adoption level. In addition, the evaluation scale developed in this study can be effectively used in assessing the readiness of the stakeholders in the supply chain for technology adoption in general.

2. Literature review

The agricultural supply chain is a connected system of individuals/ organizations, activities, information, and resources designed to cultivate, process, and move agricultural products from origination to a final destination - typically from a farm to an end customer (Ronaghi, 2021). Similarly, the pork supply chain includes different stages of activities to deliver pork from the pig breeders to consumers.

Much research has pointed out issues affecting the sustainability and resilience of agricultural supply chains. There are three widespread problems: first, the need for practical tools to help control quality, track, and verify information throughout the supply chain (Salah et al., 2019). Second, the weaknesses in demand forecasting and production planning lead to the “price drop in good harvesting seasons” phenomenon, causing severe loss to farmers' incomes (Taşkıner & Bilgen, 2021). Third, violations of social responsibility practices in agricultural supply chains are common, especially in developing countries (such as child labor, greenhouse gas emissions, and overexploitation of land, water, and ecosystem) (Devin & Richards, 2018). Blockchain is a new technology expected to help partly solve these issues.

Blockchain is simply a distributed database or ledger that is shared among the nodes of a peer-to-peer computer network in an encrypted manner. Current studies have pointed out three significant applications of blockchain technology for agricultural supply chains (Laroiya et al., 2020): First, blockchain helps enhance agricultural product traceability. Second, blockchain has features such as smart contracts that allow building trust in transactions between strangers, helping to reduce intermediaries and complicated procedures that take time, effort, and money. In addition, there are many other applications of blockchain, such as allowing close connection of information among stakeholders involved in the supply chain, thereby improving the ability to forecast demand and market fluctuations; quick recall of contaminated products; support integration of agricultural technologies 4.0 such as IoT, AI, Big Data. In particular, blockchain can also form an e-commerce agricultural product exchange with high transparency and meager low transaction costs (Shahid et al., 2020).

In the past five years, along with the explosion of blockchain application pilot projects in the agricultural supply chain, much-related research has been carried out regarding blockchain application in the agricultural supply chain. These studies focus on four main directions. First, several studies using qualitative research tools, such as case studies and in-depth interviews, have helped to assess the benefits and barriers to applying blockchain technology. For example, research by Rogerson & Parry (2020) presented the theoretical benefits of blockchain in the supply chain, such as upstream visibility, fraud countering, and a new decentralized, consensus-based trust mechanism. Research by Kamilaris (2019) indicates that blockchain technology has been used by many projects and initiatives, aiming to establish a trusted environment for building transparent food production and distribution. More transparent and sustainable, integrating key stakeholders into the supply chain. However, many issues and challenges still need to be addressed regarding technical aspects, education, policy, and legal framework (Soriano et al., 2020). Research by Sari (2021) has pointed out many obstacles to blockchain application, such as the communication gap among supply chain stakeholders and the unavailability of information about the movement history and origin of the product. Research by (Beck et al., 2017) indicates that factors such as lack of knowledge, experience in blockchain technology, high security, and privacy risks, high initial installation cost, interface complicated and confusing operations, or users lacking necessary skills are the factors that hinder the widespread implementation of blockchain technology into supply chains in general and agricultural supply chains in particular.

The second most popular research topic involves building theoretical frameworks and using quantitative research methods (such as surveys) to analyze factors affecting consumers' and stakeholders' acceptance of blockchain adoption in agricultural supply chains. Specifically, the study by Johansen (2018) indicates that usefulness, ease of use, compatibility, autonomy, relative advantage, traceability, transferability, and information security directly affect the acceptability of blockchain adoption in agricultural supply chains. Nayal (2021) has pointed out essential antecedents for blockchain application to build a sustainable agricultural supply chain, including green and lean practices, supply chain integration, supply chain risks, performance expectations, top management support, costs, internal and external environmental conditions, regulatory support, and innovation in the blockchain adoption process. In addition, the current literature also helps to identify important moderating variables that affect the adoption of blockchain applications by consumers and stakeholders in the supply chain. First, age, education level, income, and social status are factors belonging to the socio-demographic characteristics of consumers, which significantly affect their acceptance of blockchain adoption (Beck et al., 2017). According to Lindman (2017), age often negatively impacts the application trend, and vice versa; education level, income, and social status positively impact the trend of new technology adoption.

Besides, several other studies also emphasize the role of product characteristics when researching the antecedents of blockchain adoption in the supply chain. Several empirical studies reveal that meat and fresh products are often subject to higher consumer suspicion regarding the product's origin. This creates more significant opportunities for adopting technologies that support traceability, like blockchain. The business orientation of new pork businesses also influences the adoption of blockchain technologies (Ali, 2012). Businesses that want to limit the use of blockchain technologies will try to distract consumers from other factors such as price, packaging, branding, and personal relationships (Pretty et al., 2003).

Regarding theoretical models, there are three widely used models to analyze the acceptance behavior of new technology applications, including the "theory of rational action" (TRA) proposed by Fishbein & Ajzen (1976) – this theoretical model explains and predicts the determinants of individuals' behavior; “theory of planned behavior” (TPB) was developed by Ajzen (1991) by adding a new variable to the TRA model, which is perceived behavioral control; and the “technology acceptance model” (TAM) proposed by Davis (1989) to address the reasons why users adopt or reject information technology. From the above three models, the unified theory of acceptance and use of technology (UTAUT) was built by Venkatesh (2003) to explain users' behavioral intentions and usage behavior toward information technology. The UTAUT model has four core elements of intention and behavior to use IT: Performance expectations, effort expectations, social influence, and facilitation.

Although the contributions of these models to explain the technology adoption phenomenon are highly appreciated, El-Gohary (2012) and Oliveira & Martins (2011) stated that the above models are suitable for investigating technology adoption at the individual level only. In a meta-study of IT adoption models at the enterprise level, Oliveira & Martins (2011) note that the Innovation Diffusion Theory (IDT) and Technology-Organization-Environment (TOE) theory are more powerful in explaining the adoption of technology from an organizational point of view. To explore the acceptance factors at the organizational level, Tornatzky (1990) proposed the TOE model, an extension and integration of IDT and TAM. The TOE believes adopting an innovation depends on technological, organizational, and environmental characteristics. In the TOE model, the technology context is used to describe the characteristics of the technology under consideration. It includes not only the technologies already used in the organization but also the technologies that are available in the market, such as the usefulness of the technology. The relevant organizational context to organizational characteristics such as the organization's available resources (financial, human, technological) and the support of senior management. Environmental context emphasizes the scope of the organization's business activities or industry sectors, such as competitors and customers.

Some research gaps are pointed out by reviewing the current literature on blockchain adoption in agricultural supply chains.

Firstly, most previous studies have focused on assessing the acceptance level of consumers and stakeholders in the supply chain. The compatibility of blockchain technology with the existing information technology system operating in the current supply chain has yet to be thoroughly studied. Similarly, current research models have not clarified the readiness of supply chain stakeholders (such as the availability of finance, technology, and human resources). Further, the external environment (such as legal and social environment influences) has yet to be considered and clarified. In addition, lack of research in building a unified theoretical framework and broad scale to assess the stakeholders' willingness to adopt blockchain in the agricultural supply chain.

Second, the current studies mainly analyze the "adoption intention,” but very few studies measure blockchain's "adoption level" in the agricultural supply chain. This comes from the novelty of the research phenomenon, with very few experimental cases in the past period. However, with the recent proliferation of successful test cases and practical applications of supply chain management platforms based on blockchain technology, further studies are needed to clarify the factors affecting the blockchain adoption level.

Third, the moderating factors influencing the relationship between enablers and blockchain adoption level have yet to be considered. For example, some studies reveal that industrial characteristics are essential when analyzing the relationship between readiness and actual adoption.

In this study, by reviewing the existing theoretical frameworks and related studies, the TOE (Technology - Organization - Environment) theoretical model is selected as a foundation for developing a new theoretical framework for the chosen research topic. The choice of the TOE theoretical model comes from both the suitability of this model with the research objectives and the suitability of the characteristics of the pork supply chain – with the simultaneous appearance of many individuals and organizations involved in the supply chain. Next, the study conducts qualitative interviews with experts in the research field and managers directly involved in the pork supply chain to develop a new theoretical framework. Several recommendations have been made: First, the study has separated the organization factor into intra-organization and inter-organization to match the specific realities of the supply chain (existing many stakeholders, not just a single company - as in the assumption of the TOE model). Second, the study adds the adoption level factor to examine the relationship between enablers and blockchain adoption level. Third, the study adds some moderating factors (industrial characteristics and intra-organization) to comprehensively assess the relationship between enablers and blockchain adoption levels in different supply chain contexts. Finally, the observed variables for each factor in the new model are also adjusted to be consistent with the practice of the pork supply chain in Vietnam.

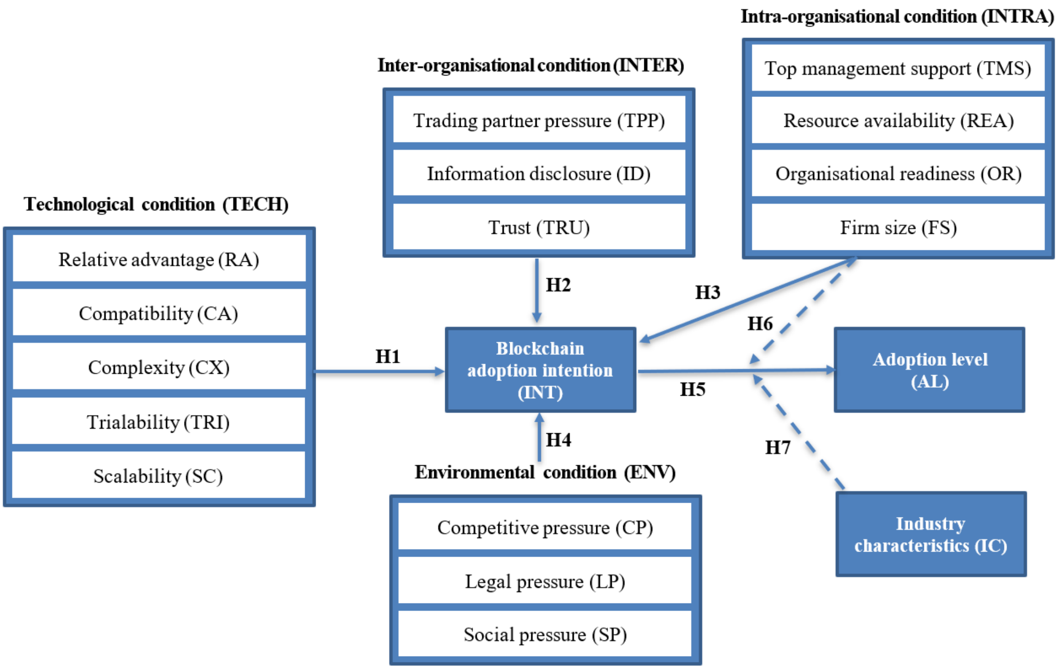

Figure 1. Proposed conceptual framework

Note: ⟶ *Direct effect* - - - ▸ *Moderating effect*

Based on the proposed theoretical framework, seven research hypotheses are suggested, including:

The relationship between technology condition (TECH) and blockchain adoption intention (INT)

From the view of TOE theory, technology readiness is considered an essential condition for the application of new technologies. The higher the readiness level, the easier and faster the adoption process. Within the supply chain management scope, five aspects of technology conditions need to be considered, including relative advantage (RA) - related to perceived usefulness and technology's ease of use; technology's effects and advantages; Compatibility (CA) - refers to technical compatibility/conformity with existing systems, ability to standardize technology across the supply chain, supply chain's flexibility/rapidly change to adapt new requirements of new technologies; Complexity (CX) - indicates the extent to which the technology is considered difficult to use; Trial Capability (TRI) - is the extent to which new technology can be tried. The likelihood of successful adoption increases when the organization has the opportunity to test the technology before it is adopted; Scalability (SC) - is the extent to which the adoption of blockchain technology can scale to all supply chain stakeholders.

Hypothesis 1. Technology condition (TECH) positively affects blockchain adoption intention (INT).

The relationship between inter-organizational condition (INTER) and blockchain adoption intention (INT)

Adopting blockchain technology requires a higher willingness to share information and trust among supply chain stakeholders. This comes from the feature of encrypting and distributing data simultaneously among the notes (users) in the blockchain. In other words, the higher the cohesion, trust, and willingness to share data, the greater the likelihood of blockchain adoption success. In this study, readiness for inter-organizational conditions (INTER) is assessed through three groups of observed variables: Trading partner pressure (TPP) - related to cohesion and long-term relationship with partners in the supply chain, the incentive to support the adoption of blockchain technology; information sharing (ID) - this is the willingness to share information/knowledge among supply chain stakeholders and the immutable informational nature of the blockchain, and blockchain's confidentiality level to shared information; Trust (TRU) - this is the trust among stakeholders. A higher trust level will allow stakeholders to believe in the focal company's decision to adopt new technology.

Hypothesis 2. Inter-organizational condition (INTER) positively affects blockchain adoption intention (INT).

The relationship between intra-organizational condition (INTRA) and blockchain adoption intention (INT)

Not only requires readiness in the relationship among stakeholders, but the adoption of blockchain technology also requires the readiness of resources in each organization. The higher the intra-organization readiness, the greater the likelihood of blockchain adoption success. The intra-organizational condition (INTRA) is assessed through four groups of observed variables, including Top management support (TMS) - which relates to top managers' technical knowledge, their commitment, and their risk tolerance when adopting new technology; Resource Availability (REA) - related to the readiness on tangible facilities, human resource, technical know-how, and finance; Organizational Readiness (OR) - refers to the organizational culture that encourages the adoption of new technologies, the ability and cooperation among departments to meet the requirements of new technologies; Firm Size (FS) - relates to capital metrics, revenue, tech-savvy human resources in supply chain stakeholders.

Hypothesis 3. Intra-organizational condition (INTRA) positively affects blockchain adoption intention (INT).

The relationship between environment condition (ENV) and blockchain adoption intention (INT)

The TOE theory also highlights two important factors when adopting new technology: Legal Pressure (LP) and Competitive Pressure (CP). Legal ambiguity and low levels of competition can dampen incentives to adopt new technologies. Conversely, in many cases, the push or even mandate from the regulatory environment will lead to high adoption rates of new technologies such as blockchain. Specifically, in this study, the regulatory environment includes government regulations, regulations of key companies in the supply chain, and agreements between companies in the supply chain on new technology adoption. On the other hand, competitive pressure from competitors and the firm's internal development needs are also crucial for promoting new technology adoption. In addition, the theoretical model in this study proposes an additional factor of social pressure (SP) - which relates to pressure from consumers, the community, and social organizations. This is also a significant driving force directly promoting blockchain adoption in agricultural supply chains.

Hypothesis 4. Environment condition (ENV) positively affects blockchain adoption intention (INT).

3. Methodology

The primary and secondary data sources are both used in this study. The secondary data is collected from the Department of Agriculture and Rural Development reports, the Department of Industry and Trade, the Food Hygiene and Safety Bureau, and the Market Management Bureau. These data provide an overview of the operation of the pork supply chain in Hue City. Next, the study collects primary data from qualitative and quantitative research to outline and analyze the proposed theoretical framework.

First, the study conducts a qualitative investigation using in-depth expert interview techniques. The group of experts includes three lecturers and researchers - experienced in research on the pork supply chain and the applications of blockchain technology in particular and seven supply chain managers from stakeholders in the pork supply chain in Hue and related local authorities. Based on the results of this qualitative research step, the study has adjusted and proposed a new theoretical model to analyze the factors affecting the adoption level of blockchain technology to develop the agricultural supply chain. Specific results are presented in the content of the proposed research model in section 2.

Next, a quantitative research step is carried out based on the survey using a structured questionnaire. The sample size is determined based on the average sample size method with n = 365 samples (Hair et al., 1998). The sample was selected based on a simple random method based on the list of firms/individuals participating in the pork supply chain in Hue City. The introduction on research objectives, consent note, and interview guidelines are sent to participants three days before meetings through email or hard copies. The official survey is conducted via phone, face-to-face, and email. The email survey sends reminder notices to participants every ten days after receiving the questionnaire.

Regarding the data analysis method, the data in the qualitative study period are continuously coded, compared, contrasted, and categorized by Nvivo 12.0 to find the core themes. With the data in the quantitative research phase, the collected surveys are filtered to eliminate inappropriate responses. Then, the SPSS 20.0, AMOS 20.0, and R 4.1.2 are run to apply the proposed analysis steps.

4. Research findings

4.1. Sample description

The statistical results indicate that pig breeders/fatteners, meat wholesalers, retail food stores, and pork sellers are the most popular stakeholder in the current pork supply chain in Hue City (33.4 % and 35.7% of the total sample). Current stakeholders have applied various information technologies, including traceability technology (QR code, RFID), sensors to monitor livestock and storage conditions, CCTV system, and means of internal information collection, storage, and sharing (Telephone, EDI system, ...), with the rate of 20.0%, 21.9%, 49.8% and 68.6% respectively.

Regarding the blockchain adoption activity, most stakeholders in the supply chain still need to be made aware of this technology (58.1%). Most businesses that know blockchain are willing to invest between 1% and 5% of total annual revenue (47.3%) and expect an additional 5% to 20% annual profit (46.0%).

Table 1. Sample description

Criteria	Classification	Frequency	%
Your firm's position in the pork supply chain	pig breeder/fattener	119	33.4
	Slaughterhouse, processor	49	13.8
	Livestock dealers	36	10.1
	Meat wholesaler, retail food store, pork seller	127	35.7
	Pork delivers, transportation firm	25	7.0
Forms of information technology being applied	Traceability technology (QR code, RFID)	71	20.0
	Sensors to monitor livestock and storage conditions	78	21.9
	CCTV system	177	49.8
	Means of internal information collection, storage, and sharing (Telephone, EDI system, ...)	244	68.6
Awareness level of blockchain technology	Never	207	58.1
	Used to, but not sure about the applicability	117	33.0
	Already know about the applicability	32	8.9
Willingness to invest *(based on annual turnover rate)*	Less than 1%	52	14.6
	From 1% to 5%	168	47.3
	From 5% to 10%	121	34.0
	Over 10%	15	4,1

Expected benefit level *(based on the annual rate of return)*	Less than 5%	57	15.9
	From 5% to 20%	164	46.0
	From 20% to 50%	86	24.1
	Over 50%	50	14.0

(Source: SPSS analysis, 2022)

4.2. Scale analysis

First, in the exploratory factor analysis (EFA) step, the principal components method with promax rotation is used. The results show that three variables - SP5, CP4, and TMS3 have factor loading factors less than 0.05 (Cudeck, 2000). So, these variables are excluded from the scale. The fourth extraction result obtains KMO = 0.900 (>0.5), with the significance level of Bartlett's Test of Sphericity being 0.000 (<0.05). The eigenvalue values of 18 extracted factors ranged from 1.006 to 17.003. The total variance extracted is 82.192% (>50%). The EFA results help the study extract 18 factors, with 62 observed variables.

Table 2. Scale analysis

Exploratory Factor Analysis (EFA)	**Re-run**	**KMO**	**Sig. Bartlett's test**		**Total variance extracted**
	1st	0.900	0.000		80.328
	4th	0.900	0.000		82.192
Confirmatory Factor Analysis (CFA)	**CMIN/DF**	**TLI**	**CFI**	**SRMR**	**RMSEA**
	1.776	0.920	0.924	0.048	0.047

(Source: SPSS and AMOS analysis, 2022)

Next, the confirmatory factor analysis (CFA) step adjusts the measurement model based on the Modification Indices (MI). This allows the proposed model to overcome the scale structure and duplication problems affecting the model fit. The results of the post-adjustment CFA analysis show that the measurement model achieves compatibility with the overall data through essential goodness-of-fit indices such as Chi-square/df is 1.776 (< 3), RMSEA is 0.047 (< 0.08), Standardized RMR is 0.048 (<0.08), TLI is 0.920 (> 0.9), CFI is 0.924 (> 0.9) met the standard as suggested by Arbuckle (2006) and Hu & Bentler (1999).

Regarding the scale's reliability, all variables have a construct reliability value greater than 0.7 and an AVE (Average variance extracted) value with a magnitude from 0.562 to 0.817, more significant than the proposed value of 0.5 (Hair et al., 1998). Similarly, conducting Cronbach's alpha test, the obtained values are all greater than the proposed value of 0.7 (Nunnally, 1978; Peterson, 1994; Slater, 1995). The proposed scale in this study thus has high reliability.

Regarding convergent value, all critical t-values have absolute values greater than 1.96 (statistically significant, p-value < 0.05), and the normalized weights are equal. > 0.5, so all concepts have convergent values.

Regarding the discriminant value, the difference between the Chi-square difference of the pairs corresponding to 18 groups of variables is greater than 3.84, so these models all achieve discriminant validity (Gerbing & Anderson, 1988). Also, the multicollinearity test shows that correlation coefficients range from 0.077 to 0.768 (less than 1), so there is no multicollinearity in the proposed scale. Comparing the square root value of the AVE of each concept with the correlation coefficients between the concepts, in the analyzed scale, the square root AVE of each concept is larger than the square of the correlation coefficients between that concept and other concepts. These results satisfy the second condition in discriminant analysis.

4.3. Structural equation model analysis (SEM)

The goodness-of-fit indices of the SEM meet all requirements, with Chi-square/df is 1.762 (< 3), RMSEA is 0.046 (< 0.08), Standardized RMR is 0.047 (<0.08), TLI is 0.923 (> 0.9), CFI is 0.927 (> 0.9) (Arbuckle, 2006; Hu & Bentler, 1999).

Table 3. SEM analysis results

Factor relationships			S.D.	C.R.	P	Standardized coefficients
INT	<---	TECH	.307	3.787	***	.785
INT	<---	INTER	.136	2.277	.023	.147
INT	<---	INTRA	.075	2.664	.008	.135
INT	<---	ENV	.252	.357	.721	.067
AL	<---	INT	.051	12.415	***	.631

Notes: *Estimate: estimated value; S.D.: standard deviation; C.R.: critical value*

*** - *equivalent to a value of 0.000*

(Source: AMOS analysis, 2022)

The results of SEM analysis show that four of the five tested hypotheses are significant, with a p-value < 0.05. Technology condition (TECH), inter-organizational condition (INTER), and intra-organizational condition (INTRA) have a strong, positive impact on blockchain adoption intention (INT) (regression coefficients are .785, .14,7, and .135, respectively). Moreover, adoption intention (INT) also has a very strong impact, positively, on the adoption level (standardized regression coefficient is .631). The hypothesis about the effect of environmental condition (ENV) on adoption intention (INT) alone is not significant (p-value is .721 > .05).

In addition, the SEM analysis results also imply that three independent variables - technology condition (TECH), inter-organizational condition (INTER), and intra-organizational condition (INTRA) also have an indirect and positive impact on the adoption level (AL) (standardized total effects are 0.495, 0.093 and 0.085 respectively).

Table 4. The indirect influence of independent variables on adoption (AL)

		INTER	INTRA	ENV	TECH
AL	Total Effects	0.196	0.126	0.057	0.737
	Standardized Total Effects	0.093	0.085	0.043	0.495

(Source: AMOS analysis, 2022)

4.4. Bootstrap test

To evaluate the sustainability of the theoretical model, the study uses the Bootstrap analysis method. This is a method of repeated sampling with substitution from the original sample, in which the primary sample plays the role of the crowd (Schumacker & Lomax, 2004). The number of repeat sampling times is 1000. This Bootstrap test is used to check the reliability of the regression coefficients in the SEM model.

Hypotheses H_0 : Bias = 0, H_1: Bias ≠ 0

Table 5. Bootstrap test results

Factor relationships			Estimate	Mean	Bias	SE-Bias	CR
INT	<---	TECH	0.447	1.220	0.056	0.014	0.011
INT	<---	INTER	0.131	0.329	0.019	0.004	0.012
INT	<---	INTRA	0.072	0.206	0.006	0.002	0.010
INT	<---	ENV	0.412	0.034	-0.056	0.013	0.382
AL	<---	INT	0.052	0.629	-0.004	0.002	0.003

(Source: AMOS analysis, 2022)

The results in Table 5 indicate that the absolute values of CR are all smaller than the test value of 1.96, so it can be said that the bias is minimal, not statistically significant at the 95% confidence level, or in other words, the result of the estimate B=1000 times from the original sample is averaged. This value tends to be close to the estimate of the population, resulting in the bias of the estimate (bias) and its standard deviation small and stable value. Therefore, we can conclude that the estimates in the SEM model are reliable.

4.5. Moderation test

Table 6. Moderation test results

Model	DV	IVs and Moderating Variables	Coefficient	*p*
1	Blockchain adoption level (AL)	Adoption intention (INT)	.314	***
		Industry characteristics (IC)	.267	***
		INT × IC	.200	***
		Model 1 R^2	0.649	
2	Blockchain adoption level (AL)	Adoption intention (INT)	.552	***
		Intra-organization condition (INTRA)	-.065	.161
		INT × INTRA	-.047	.307
		Model 2 R^2	0.304	

**** The test significance level is lower than 0.05*

(Source: AMOS analysis, 2022)

The moderation tests are performed to test the influence of moderating variable - industry characteristics (IC) and intra-organizational condition (INTRA) on the relationship between blockchain adoption intention (INT) and adoption level (AL). The results in Table 6 below indicate that, in model 1, all three hypotheses are significant, with p-values less than 0.05. The proposed model has a high fit, with the R2 value reaching 0.649. Notably, the standardized coefficient of the impact of the interactive variable (INT × IC) is 0.200 (greater than 0). This means that if supply chain characteristics require more traceability and information sharing, the impact of blockchain adoption intention (INT) on the adoption level (AL) will increase.

In Model 2, both hypotheses related to the intra-organizational condition (INTRA) impact are insignificant, with p-values greater than 0.05 (0.161 and 0.307, respectively). This indicates that intra-organizational conditions (INTRA) have no clear moderating impact on the relationship between blockchain adoption intention (INT) and adoption level (AL).

4.6. Differences in the assessment of adoption readiness

This analysis step is based on One way ANOVA test. It is performed to examine the differences in the assessment of adoption readiness of stakeholders in the pork supply chain (pig breeders/fatteners; slaughterhouse, processor; livestock dealers; meat wholesaler, retail food store, pork seller; pork delivers, transportation firm). The analysis results in Table 7 show that there are differences in the assessment of resource availability (REA), firm size (FS), scalability (SC), and social pressure (SP) (Sig values of Anova test are .036, .001, .013 and .027 respectively, all less than .05).

Table 7. Differences in the assessment of adoption readiness

Criteria	*Sig. Levene's test*	*Sig. ANOVA*
Relative advantage (RA)	0.215	0.092
Compatibility (CA)	0.994	0.393
Complexity (CX)	0.801	0.416
Trialability (TRI)	0.581	0.715
Scalability (SC)	0.273	0.013
Trading partner pressure (TPP)	0.081	0.205
Information sharing (ID)	0.462	0.790
Trust (TRU)	0.313	0.135
Top management support (TMS)	0.149	0.735
Resource Availability (REA)	0.054	0.036
Organizational Readiness (ORG)	0.604	0.633
Firm Size (FS)	0.518	0.001
Competitive pressure (CP)	0.746	0.356
Legal pressure (LP)	0.858	0.516
Social pressure (SP)	0.227	0.027

(Source: SPSS analysis, 2022)

5. Discussion

Based on the SEM analysis results, technological conditions (TEC), inter-organizational conditions (INTER), and intra-organizational conditions (INTRA) are three factors that have a direct, positive impact on blockchain adoption intention (INT). Meanwhile, adoption intention (INT) also has a very strong direct impact on the adoption level (AL). This result is relatively consistent with the research results of Johansen (2018). Interviewing stakeholders participating in the pork supply chain in Hue reveal that technological conditions (such as the superiority of blockchain compared to existing technologies, the compatibility of blockchain with the existing information management system, and the moderate complexity of the new technology) dramatically impact their adoption consideration. Because most of the stakeholders in the pork supply chain in Hue are individuals and households with a relatively low level of technical proficiency and low ability to grasp new technologies. Similarly, the requirements for trial and scalability are also considered essential for stakeholder decision-making. In addition, the intra-organizational condition (such as the support from top managers, the availability of financial and human resources, and the fit with the organizational culture) also plays a vital role during the adoption consideration process. Lastly, the inter-organizational condition (such as focal companies' encouragement, willingness to share information, and trust) also plays a vital role in blockchain adoption decisions.

In contrast, the environmental condition (ENV) has no significant impact on blockchain adoption intention (INT) (p-value < 0.05). This is in contrast to the results of Nayal (2021). This comes from two reasons: first, in Vietnam - a developing country- very few non-profit organizations (NGOs) are operating to protect consumers' interests or against firms with unsustainable business practices. Secondly, the issue of blockchain adoption still needs to be discovered by consumers and government agencies in Vietnam. Hence, the concern and pressure level on its adoption in current firms is almost nonexistent.

Another interesting finding indicates that technological conditions (TEC), inter-organizational conditions (INTER) and intra-organizational conditions (INTRA), and blockchain adoption intention (INT) have a strong indirect and direct impact on adoption level (AL). Because the pork supply chain in Hue, Vietnam, is quite diverse in terms of participants - from very small individuals to huge enterprises, the readiness level of stakeholders is, therefore, very diverse. This leads to differences in investment willingness for blockchain adoption.

The results of the moderating test imply that in a supply chain with higher requirements on traceability and information sharing, the impact of the blockchain adoption intention (INT) on the adoption level (AL) will increase. This is rooted in the fact that with more strict control of product quality, more legal pressures and greater attention by top managers will appear on moving from intention to adoption decision.

The analysis results of the differences in blockchain adoption readiness among stakeholders in the supply chain show a clear difference in resource availability (REA), Firm scale (FS) assessment. This is consistent with the results of Nayal (2021). Because depending on the business process requirements, each stakeholder in the supply chain has a different capital availability and number of employees. While livestock dealers, pork deliveries, and transportation firms typically have low resource availability for blockchain investment. The remaining stakeholders (such as pig breeders/fatteners, slaughterhouses, pork processors, meat wholesalers, retail food stores, and pork sellers) typically have higher resource readiness for blockchain investments. Another difference relates to social pressure (SP), which comes from the fact that stakeholders further down the supply chain (such as meat wholesalers, retail food stores, and pork sellers) are often more familiar and more directly with the consumer community and local regulatory agencies. Therefore, the pressure to apply new technologies to prove the origin and quality of products is also higher.

6. Conclusion

Through studying the factors affecting blockchain adoption level to develop agricultural supply chains, with the case study of the pork supply chain in Hue, the study has contributed both academic and practical aspects.

Firstly, through the qualitative research step, the study outlines a new theoretical framework to evaluate the factors affecting blockchain adoption in the agricultural supply chain. Compared with the TOE theoretical model, this new theoretical framework adds an inter-organizational conditioning (INTER) element. In addition, the observed variables of each factor are also adjusted, such as the scale of technological conditions (TECH) adds scalability (SC). The environmental conditions (ENV) scale adds social pressure (SP). In general, the evaluation scale developed in this study can be effectively used in assessing the stakeholders' adoption readiness for blockchain in various research fields and different developing country cases.

Second, compared with the TOE theoretical model, the study expands to assess the antecedents of blockchain adoption level (AL) instead of just stopping at adoption intention (INT). This is also an essential suggestion for similar studies on technology adoption in the supply chain.

Third, the study also contributes to examining the influence of industry characteristics on the relationship between stakeholders' readiness and their adoption decision. This is also important to consider when applying the research model to areas with different levels of information sharing and traceability requirements.

From the practical side, the results from this study help to point out the most significant barriers and the aspects that need to be prioritized for preparation when stakeholders consider investing in blockchain technology. In addition, the statistics on stakeholders' investment willingness and readiness also help focal companies determine the feasibility of a potential blockchain adoption project. Further, the built-in survey scale can be used effectively in measuring the adoption level of each stakeholder in the supply chain.

In general, the research results meet all of the initial objectives. However, due to time and budget limitations, the study still has some unavoidable limitations in its implementation. The study is conducted with a single pork supply chain and a single site in Hue, Vietnam. Further studies are needed to assess more diverse product categories in other countries worldwide to enhance the representation of study results to all agricultural supply chains.

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Appendix 1. Measurement scale of factors affecting the adoption level of blockchain technology to develop agricultural supply chains

Factor	Assessment criteria
Relative advantage (RA)	Blockchain improves pork traceability better than existing technologies.
	Blockchain helps improve transparency and increase trust among stakeholders in the pork supply chain.
	Blockchain helps to improve payment efficiency faster than existing methods.
	Blockchain helps in forecasting demand more accurately than existing technologies.
	The cost of applying blockchain technology is relatively lower than other IT solutions.
Compatibility (CA)	Blockchain characteristics are suitable for sharing data from existing IT systems.
	Existing technologies are technically complementary to blockchain technology adoption.
	Blockchain adoption will not negatively affect the operation of existing technologies in the supply chain.
Complexity (CX)	Blockchain adoption requires too much new technological knowledge.
	Blockchain adoption requires too much skill in leveraging new technology.
	Blockchain adoption requires an extremely high level of information-sharing among stakeholders in the supply chain.
	It will take much time and effort to popularize how to use blockchain.
Trialability (TRI)	Blockchain can deploy applications on a small scale with a correspondingly smaller investment.
	The small-scale adoption does not change the efficiency of blockchain compared to the large-scale adoption.
	The cost and time to apply small-scale blockchain applications are similar to the case of large-scale adoption.
	After deploying the blockchain applications on a large scale, the stakeholder can still easily cancel the applications if there are problems.
Scalability (SC)	Stakeholders can easily standardize ways of adopting blockchain to the pork supply chain.
	Stakeholders can easily duplicate the blockchain adoption model for other stakeholders.
	The cost of initial investment and maintenance of blockchain applications is suitable for most stakeholders in the supply chain.

	Blockchain can easily customize different application configurations to match the existing information system characteristics of each stakeholder in the supply chain.
Trading partner pressure (TPP)	The stakeholders will apply blockchain if major trading partners in the supply chain recommend/request to apply.
	The stakeholders believe that blockchain applications will help increase cohesion and long-term relationships with partners in the supply chain.
	Major trading partners will provide financial and technological support if the stakeholders deploy a blockchain application.
Information sharing (ID)	The stakeholders are willing to disclose all information about pork operations/trading activities.
	The immutable information property of the blockchain does not affect stakeholders' willingness to share information.
	The blockchain's encryption and real-time information retrieval characteristics do not affect stakeholders' willingness to share information.
	The safety level of blockchain technology for shared information is very high.
Trust (TRU)	You believe that blockchain adoption is purely to support better supply chain management.
	You completely trust that the partner will not use the shared information maliciously.
	Stakeholders in the supply chain have high confidence in the commitments of their partners.
Top management support (TMS)	Blockchain adoption suits the stakeholders' current business model and development orientation.
	The stakeholders' top management team has high commitment and support for adopting new technologies.
	The stakeholders' top management team has a high level of knowledge about new technologies.
	The stakeholders' top management team can accept risks related to blockchain adoption.
Resource Availability (REA)	The stakeholders have full tangible facilities and suitable equipment to apply blockchain technology.
	The stakeholders have the personnel with the necessary expertise and skills to adopt blockchain.
	The stakeholders have enough financial resources to invest in blockchain technology and maintain the application for a long time.

Organizational Readiness (ORG)	The organizational culture of the stakeholders encourages the adoption of new technologies.
	The stakeholders have experience in adopting new ITs.
	Blockchain technology can be easily integrated into existing firms' operations.
	The stakeholders can change quickly to adapt to the requirements of new technology.
Firm Size (FS)	Your firm's capital is more substantial than other stakeholders in the supply chain.
	Your firm's revenue is higher than other stakeholders in the supply chain.
	Your firm has more tech-savvy employees than others in the supply chain.
Competitive pressure (CP)	Blockchain can be considered the foundation for developing new competitive capabilities of the stakeholders.
	Blockchain adoption will give your firm a more decisive competitive advantage.
	Blockchain adoption makes it easier for stakeholders to penetrate markets with high requirements for proof of origin and quality control.
	Your firm believes that competitors have recently begun to explore Blockchain technology.
Legal pressure (LP)	New food safety regulations promote blockchain adoption in the pork supply chain.
	Authorities encourage blockchain adoption in the pork supply chain.
	Current supply chain regulatory systems are suitable for blockchain adoption.
Social pressure (SP)	Customers would be interested in the benefits of blockchain application
	Customers would be willing to pay more for products with blockchain applications.
	Social activists (consumer protection organizations) are interested in information about blockchain adoption.
	News on social networks and media channels affects the stakeholders' demand for blockchain adoption.
	Information about cryptocurrency has little impact on the perception of the benefits of blockchain for the supply chain.