Key theories and research models for assessing factors affecting the adoption of traceability technologies in agriculture: A systematic literature review

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Các lý thuyết và mô hình nghiên cứu nền tảng nhằm đánh giá các nhân tố ảnh hưởng đến việc áp dụng công nghệ truy xuất nguồn gốc trong nông nghiệp: Tổng quan tài liệu có hệ thống

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ABSTRACT

This study identifies and measures the factors influencing the adoption of traceability technologies in agriculture to inform policymakers, government authorities, and enterprises in developing digital-transformation strategies for sustainable agriculture. Using a systematic literature review (SLR) method, publications from indexed Scopus and Web of Science between January 1, 2019 and June 30, 2025 were synthesized. The review focuses on prominent theoretical frameworks, including the Diffusion of Innovation (DOI), Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Technology - Organization - Environment (TOE) framework. By evaluating the relative strengths and limitations of these theories and models, the study proposes the TOE framework as the most comprehensive foundation for subsequent qualitative and quantitative research. Furthermore, the findings highlighted the potential for integrating these frameworks to identify critical determinants and establish a robust model for measuring agricultural traceability technology adoption, specifically tailored to the Vietnamese context.

Từ khóa:
Chấp nhận công nghệ, Khung Công nghệ - Tổ chức Môi trường (TOE), nông nghiệp bền vững, tổng quan tài liệu có hệ thống, truy xuất nguồn gốc.

TÓM TẮT

Nhằm nhận diện và đo lường các nhân tố ảnh hưởng đến việc áp dụng công nghệ truy xuất nguồn gốc nông sản, nghiên cứu đã thực hiện tổng quan tài liệu có hệ thống (SLR) các công bố từ hệ thống Scopus và Web of Science giai đoạn 01/01/2019–30/6/2025. Nghiên cứu tập trung phân tích các lý thuyết và mô hình phổ biến như: Lý thuyết Lan truyền Đổi mới (DOI), Lý thuyết Hành vi có Kế hoạch (TPB), Mô hình Chấp nhận công nghệ (TAM), Lý thuyết Hợp nhất về Sự chấp nhận và Sử dụng Công nghệ (UTAUT) và khung Công nghệ - Tổ chức - Môi trường (TOE). Trên cơ sở đánh giá ưu nhược điểm của các mô hình, nghiên cứu đề xuất khung TOE là mô hình tối ưu cho các nghiên cứu định tính và định lượng tiếp theo. Đồng thời, kết quả cũng chỉ ra khả năng tích hợp các mô hình khác vào việc xác định và đánh giá các nhân tố ảnh hưởng đến áp dụng công nghệ truy xuất nguồn gốc nông sản tại Việt Nam, góp phần hỗ trợ các cơ quan quản lý và doanh nghiệp trong việc xây dựng chính sách và chiến lược chuyển đổi số nông nghiệp bền vững.

1. INTRODUCTION

The global agricultural sector is undergoing a profound transformation under the dual impact of digitalization and sustainable development [1]. In Vietnam, increasingly stringent requirements from major agricultural import markets such as the European Union's Farm-to-Fork (F2T) regulations and green customs clearance channel for imports into China create an urgent need for enhancing transparency and traceability throughout the Vietnamese agricultural supply chain. In the domestic market, consumers are also more concerned about the origin of products and are willing to pay a premium for traceable products. Therefore, the adoption of traceability technologies within an appropriate legal

framework for digital transformation, food safety and sustainable agricultural development is essential to promote both exports and domestic markets for agricultural products. In this context, the agricultural supply chain, comprising diverse stakeholders and actors such as farmers, agricultural cooperatives, purchasers, processors and distributors and exporters, have been reshaped to address both the variability in supply capacity and the increasingly stringent quality and traceability requirements for agricultural products throughout the chain.

Since the early 2000s, the concept of traceability has shifted from "trace", "track" to "follow" in official documents of the International Organization for Standardization (ISO), the Food and Agriculture Organization of the United Nations (FAO), and the World Health Organization (WHO). Accordingly, traceability in agriculture is defined as the ability to access specific product information that has been collected and integrated with product identification information throughout the entire supply chain [2]. New technologies, especially blockchain technology, have emerged in the field of traceability since 2019, giving producers and businesses in the agricultural industry more capabilities to effectively monitor different stages of the agricultural supply chain [3]. Agriculture 4.0 (Agri 4.0) which refers to the digital transformation process in agriculture through the application of information and communication technology (ICT), enables automation, data-driven planning and value chain connectivity to enhance efficiency, transparency and sustainability [4]. In this context, the adoption and individual/single technology or their integration of many different technologies from blockchain technology, Internet of Things (IoT), big data, Radio Frequency Identification (RFID), Near Field Communication (NFC), sensors, ..., helps increase transparency in product origin, strengthen data reliability, prevent fraud in its traceability to ensure compliance with regulations and enhances value creation in the agricultural supply chain. Consequently, research on traceability technologies, which has attracted interested from early 2000s, has been increasing significantly since 2019 with wider application of blockchain across industries and areas (Figure 1).

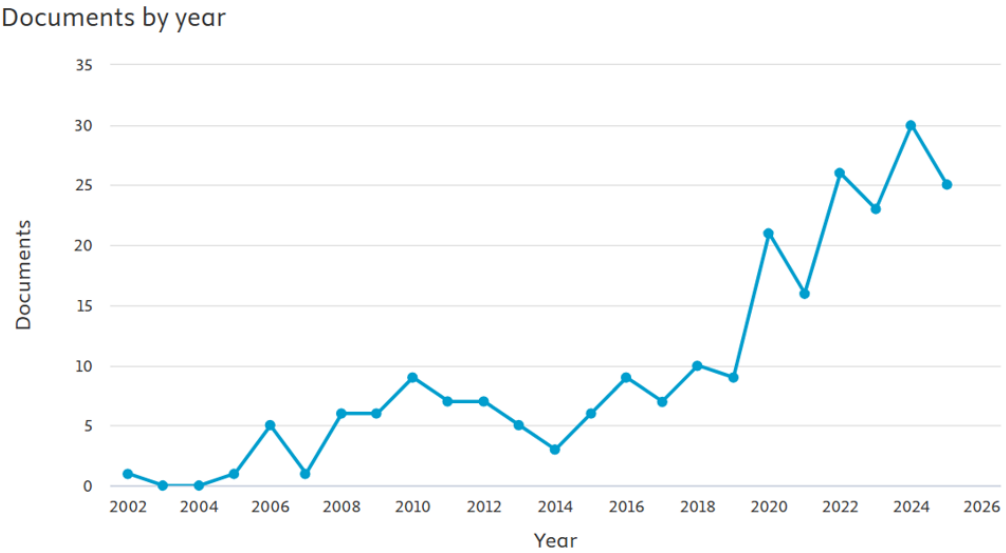

Figure 1. Number of publications on Scopus on traceability technologies in agriculture (2002 – June 2025)

Although the increasing trend in the number of publications (Figure 2) reflects growing academic interest, the majority of studies (approximately 80-90%) emphasize technical solutions aimed at improving operational efficiency and enhancing the applicability of technology in practice. In contrast, research on factors affecting the adoption of traceability technologies from business and management perspective remains limited in both quantity and scope. Most existing research focused on systematizing previous studies and proposing future directions. Only a few studies published

from 2021 onward, predominantly from China, have explored the selection of theories and models, applying a range of methods such as representative case studies, Q methodology, in-depth interviews and surveys, analysis and testing of research models. These studies have identified several factors affecting the adoption of traceability technologies across different scopes and contexts of the agricultural sector and showed their potential to be applied in the future.

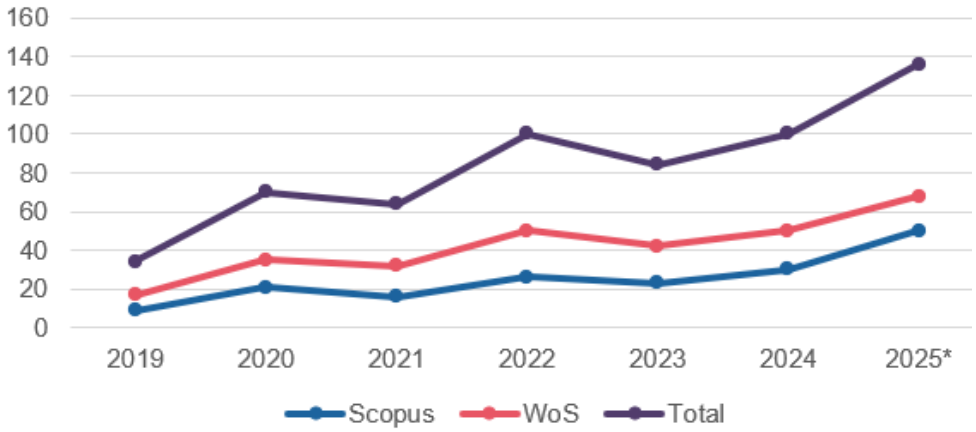

Figure 2. Summary of publications on traceability technologies in agriculture indexed in Scopus and WoS (2019 – June 2025)

In Vietnam, to meet the growing demand for domestic food safety information and quality control of agricultural products for export, the adoption of traceability technologies is essential for sustainable development in the agricultural sector. At the same time, research on factors affecting the adoption of traceability technologies in the agricultural sector worldwide along with associated theories and research models is needed to provide adequate insights for proposing effective economic management solutions. To address this research gap, this article employs a systematic literature review (SLR) methodology to identify potential theories and research models that are relevant to assessing factors affecting the adoption of traceability technologies in agriculture. Specifically, the article seeks to answer the following research questions:

• What are the key theories and research models that examine the factors affecting the adoption of traceability technologies in agriculture sector in the world?

• Which research model or theory can be applied to study the factors affecting the adoption of traceability technologies in the agricultural sector in Vietnam?

Based on a thorough assessment of peer-reviewed journal articles indexed in Scopus and Web of Science database between 01 January 2019 and 30 June 2025, the article is structured into three other main sections to detail the research methodology; present key findings and discussion; and conclude with implications, limitations, and directions for future research.

2. RESEARCH METHODS

The study was conducted using the Systematic Literature Review method with 4 steps of the PRISMA model [5]. The scope of the study was limited to scientific articles and reports published on the Scopus and Web of Science systems in the period from 01 January 2019 to 30 June 2025. This period marked the emergence of blockchain along with existing technologies such as IoT, sensors, or NFC, which broadened the research scope from basic concepts and potential uses in traceability to a wide range of systematic literature reviews and diversified studies on the application of traceability technologies in agriculture, both from technical and managerial perspectives. The boom in number of research (Figure 1) and the growth of extensive studies during 2019–2025 also enhanced empirical research using qualitative and quantitative methods, which are the focus of this study.

Keywords used to search on the Scopus and Web of Science systems were selected according to the Cochrane Guidelines and

Boolean logic. In order to avoid missing important research in the context of limited research on traceability technologies, the final search string was expanded with the combination of TITLE-ABS-KEY (("traceability technologies" OR "traceability system" OR "food traceability") AND ("adoption" OR "implementation" OR "uptake" OR "acceptance") AND ("agriculture" OR "agricultural" OR "farming" OR "agri-food")) AND PUBYEAR > 2019 AND PUBYEAR < 2025. Accordingly, 150 articles on Scopus and 113 articles on Web of Science were found. After the preliminary screening of the title and abstract, 57 duplicate articles and 106 articles unrelated to the scope of management and factors affecting the adoption of traceability technologies were eliminated. In addition to seven articles that were not accessible, 93 articles were screened in full text to answer the two research questions. However, to select the most appropriate framework for empirical research in Vietnam, the author excluded all articles that did not employ an empirical methodology (either qualitative or quantitative) or did not use any theory or research model to test hypotheses. Therefore, to answer these specific questions, only 12 articles were read in depth, thoroughly analyzed and evaluated, and the findings were synthesized in relation to five theories and models. Among these, one model was identified as the most suitable for examining the factors affecting the adoption of traceability technologies in Vietnam's agricultural sector.

3. RESULTS AND DISCUSSION

Recognizing that every methodological approach has its inherent limitations, this article adopted an SLR structure to ensure both systematic and objective findings. By employing formal and ethical procedures, validity and reliability were maintained throughout the process. The article analyzed and synthesized the literatures, identifying five key theories and frameworks (Table 1) that have been applied globally in examining factors affecting the adoption of traceability technologies in agriculture as follows.

Table 1. Summary of key theories and models in recent research on traceability technology adoption

Theory/Model/Framework	Author, year	Empirical methodology	Reference
Diffusion of Innovations	Fu & Huang, 2024	Questionaires and Q methods	[8]
Theory of Planned Behavior	Huang & Fu, 2023	Questionaires	[14]
Technology Acceptance Model	Huang & Fu, 2023 He et al., 2023	Questionaires	[17, 18]
Unified Theory of Acceptance and Use of Technology	Li et al., 2024	Questionaires	[20]
Technology - Organization - Environment	Yap et al., 2023 Li et al., 2024	+ In-depth interview + Questionaires	[22, 9]
No Theory/ Model/ Framework	Ali et al., 2024 Asfarian et al., 2025 Lai et al., 2025 Parra Lopez et al., 2025 Zhu et al., 2024	+ Case studies + Questionaires + Interview (with experts) + Game analysis	[15, 23, 24, 25, 26]

3.1. Diffusion of Innovations (DOI)

Since 1962, Everett Rogers (2023) [6] has argued in the Diffusion of Innovations Theory that the adoption of innovations follows a predictable pattern over time, influenced by factors such as Relative Advantage, Compatibility, Complexity, Trialability, and Observability. Accordingly, the process of an innovation such as the adoption of a traceability technology into an agricultural production facility, does not occur on a mass scale at once but rather progress group by group (pioneers, followers, majority...) creating acceptance among pioneer group and then spreading in society in a predictable pattern over time. Thus, adoption depends not only on the technology itself but also on the social system and communication channels. These are factors that help explain the speed of influence on the decision to quickly or slowly adopt traceability technology in agriculture.

In their 2024 publication, Fu et al. (2024) [7] used the Q-methodology combining qualitative and quantitative research and interviewed 31 farmers in China to find and test the factors that influence farmers' perceptions of the technological characteristics of the traceability system. However, although a later study by Li et al. (2025) [8] showed a positive relationship between the perception and the support of top management in enhancing technology adoption, it did not find statistical evidence that the above-mentioned Relative Advantage and Complexity factors have an influence on the adoption of traceability technology in agriculture. In other words, the inconsistency in research findings raises questions about the effectiveness of applying the Diffusion of Innovation Theory with its five factors as either a comprehensive research model or a fundamental theoretical basis for identifying and measuring factors influencing the adoption of traceability technologies.

3.2. Theory of Planned Behavior (TPB)

The Theory of Planned Behavior (TPB), proposed by Icek Ajzen (1991) [9], explains that an individual's process on adopting technology is influenced by three factors: Attitude, Subjective norms, and Perceived behavioral control. In agriculture sector, this theory has been applied in research on green farming technologies in China, pest control technologies in the Chinese tea industry, and so on where individual farmers make their own decisions on investment and adoption of technology [10-12]. In the context of traceability, Huang et al. (2023) [13] interviewed 408 fruit farmers in China and analyzed the data to confirm the positive relationship between the three factors of TPB Theory and two additional factors: Moral norms, and Safety awareness on farmers' willingness to participate in the traceability system aimed at sustainable agricultural transformation. Both studies focused on individual decision making in applying the theory despite their deployment of different sets of factors.

However, in reality, the agricultural supply chain consists of production and business units of different sizes associated with different levels of decision-making power [14]. Therefore, limiting research to individual households associated with their individual decision-making processes represents a critical shortcoming of the theory, preventing its application to study the adoptions of traceability technologies throughout the agricultural supply chain. In addition, similar to the DOI theory, studies with TPB have largely focused on awareness and intention to adopt, without identifying and assessing factors that influence adoption decisions. This limitation hinders the development and application of a comprehensive research framework.

3.3. Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) is a model initially developed by Fred Davis and extended to explain and predict users' acceptance and use of technology [15]. The model focuses on how users evaluate and choose to use new technology through two basic factors: Perceived Usefulness and Perceived Ease of Use. Then, the model was integrated with the factors of the above-mentioned TPB theory and the Goodhue and Thompson's Task-Technology Fit Model in examining the perceived usefulness and ease of use of technology; thereby, emphasizing and measuring the role of behavioral intention in shaping practical application.

Among the four studies using the TAM model, two studies have expanded the basic factors of the TAM model by adding the new factors such as Moral norms, Policy support, Transaction cost, Satisfaction, etc. [16, 17]. However, despite the additional factors, empirical results only demonstrate that the model effectively explains the intention and behavior of adopting selected traceability technologies. Clearly, TAM demonstrates greater advantages than TPB in studying the adoptions of traceability technologies across a wide range of entities, from individual farmers to organizations of different scales in the agricultural supply chain. However, even in the expanded TAM models, they have not considered the internal aspects of the organization such as farm size, income level, and level of socialization of the organization at the time of the study [16, 17]. Some other factors such as business environment characteristics associated with cultural factors and markets are also being overlooked. For that reason, the decision-making in adopting

traceability technologies was not comprehensively studied in either qualitative or quantitative methodologies.

3.4. Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT), proposed by Venkatesh et al. in 2016, considers four factors: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions [18]. These determinants of intention to use and adoption behavior are derived from eight previous theories and models, including the three theories and models mentioned above (DOI, TPB, TAM). The UTAUT theory successfully synthesizes earlier theories into a comprehensive and unified analytical framework to better explain potential user's intention to use and actual adoption behavior of technology; therefore, it is highly regarded in research on traceability technology adoption.

In 2024, this theory was applied to examine the application of Internet of Things technology in agricultural traceability in China, but the study with 357 samples did not find sufficient statistical evidence of the influence of these factors on the intention to adopt Internet of Things traceability technology [19]. The explanation given is that the theory is not suitable for research in the contexts where decision-making occurs within organizations that must follow established rules. Meanwhile, such organizational decision-making and rules are critical for traceable quality control in agricultural supply chains, especially for exports or emerging domestic demands in Vietnam. In addition, some other organization and environment factors such as cultural background, organizational structure and corporate governance, environment and market conditions have not been considered to align with the legal and market requirements for practical application. For that reason, the theory has the same limitation as the above-mentioned DOI, TPB, and TAM in terms of coverage of selected factors for study, particularly in organizational level.

3.5. Technology - Organization - Environment (TOE)

Different from the focus on individual intentions and behaviors in the aforementioned models and theories, the Technology - Organization - Environment (TOE) Framework proposed by Tornatzky and Fleischer considers three main dimensions affecting the adoption and implementation of technology in organizations, including Technology, Organization, and Environment [20]. Accordingly, the TOE framework provides a comprehensive view of human and non-human factors in studying the adoption and diffusion of technology, allowing for flexible selection of factors relevant to each dimension under various conditions and technologies [8]. As a result, the coverage of factors selected for study could be broadened to strengthen the validity and comprehensiveness of empirical research.

In addition, the flexibility in selecting factors enables the integration of each aspect of Technology, Organization, and Environment into the TOE comprehensive model, thereby enhancing its synthesis and explanatory power. For example, the study by Li et al. [8] incorporated the two factors Relative Advantage and Complexity from the DOI Model when examining the Technology aspect. Meanwhile, another Li's research group [19] replaced Relative Advantage with Compatibility from the DOI model to assess the Technology impact. Conversely, Yap et al. (2025) [21] synthesized multiple independent research results to identify five criteria for evaluating Technology including Transparency, Reliability, Disintermediation, Complexity, and Digital Competence. The advantage from flexibility in defining these factors within the TOE framework have produced diverse research outcomes. In other words, the acceptance of certain hypotheses across different empirical studies further highlights that selecting appropriate factors are critical to formulating reasonable hypotheses and effectively explaining the drivers of traceability technology adoption in agriculture.

Moreover, the TOE framework allows for proactive adjustment by shifting focus from the Organizational aspect to the Individual aspect and vice versa. For instance, a study on factors affecting the application of the Internet of Things by vegetable farmers [19] confirmed the validity of the hypothesis and the reliability of the model after replacing Organization-related factors with Individual-

level factors (specifically, Cognitive Interaction and Farmer Innovation). This adaptability creates more opportunities for applying the TOE framework rather than above mentioned theories and models in the study of traceability technologies adoption across the supply chains that involve diverse actors with different scales and business characteristics, ranging from individual farming households to large companies and corporations.

4. CONCLUSION

An overview of the application of five theories and models (DOI, TPB, TAM, UTAUT, and TOE) in the agricultural sector in the world, including Vietnam, in recent years shows the diversity and complexity in the application of these traceability technologies. Each theory or model provides different insights, perspectives, and values. However, with the goal to respond our two research questions to select a theory or model to identify and evaluate factors affecting the adoption of traceability technologies in the agricultural sector in Vietnam in the future, the study has drawn the following points:

First, given its focus on factors affecting the application of technology in the organizational context, the TOE framework is the optimal choice in studying factors affecting the adoption of traceability technologies in both production and business units in the agricultural supply chains. Specifically, the TOE framework has advantage as it allows the consideration of factors at both organizational and individual levels. As studied by Yap et al. [21], the factors of formation of alliances and organizational culture exemplify how TOE is suitable for agricultural supply chains studies, where business entities range from individual farmers to organizations of various scales.

Second, current studies using the TOE framework differ considerably in the factors employed across all three aspects of Technology, Organization, and Environment. The identification of these factors is currently based on other models (such as DOI, TPB, ...) or on the comprehensive assessment of different studies (such as premium price, government arrangement, learnability characteristic, consumer risk aversion level [22-25]. This leads to the development of different hypotheses and varying test results. Therefore, the identification of appropriate influencing factors for each aspect needs to be carefully considered and grounded in comprehensive and multidimensional review studies.

Third, although the DOI, TPB, UTAUT theories as well as the TAM model are not the optimal models for studying traceability technologies adoption in predominantly organizational contexts, some factors of these theories and models have been confirmed their validity and effectiveness in explaining the intention and behavior of adopting traceability technologies among business and production entities in previous studies. Therefore, a thorough study of these factors, in conjunction with the possibility of adjusting related factors, can help build a set of affecting factors with suitable hypotheses for the study. Accordingly, a thorough study of these factors should be conducted in the early stages of research to identify and validate influencing factors.

Finally, although the study by Li et al. [19] demonstrated the suitability of the hypothesis and the explanatory power of the model when adjusting from the Organizational context to the Personal context, this adjusted TOE framework needs further testing through similar studies, including in other context and different agricultural products. Then, the application of this adjusted TOE model to all subjects of the study from individual production and business households to production and business organizations in the entire supply chain will be more feasible in the future.

Although limited in scope to the period from January 2019 to June 2025, and restricted to articles published in Scopus and Web of Science, the study has made initial theoretical contributions by demonstrating the feasibility of selecting the TOE framework in studying factors affecting the adoption of traceability technologies in the agricultural sector in Vietnam as well as proposing the use of DOI, TAM, TPB, and UTAUT models in selecting factors for the Technology, Organization, and Environment dimensions of the TOE framework. Therefore, the future research should begin by assessing key factors of these theories and models that best fit with the TOE framework for the adoption of traceability technologies in agriculture and then proceed to test the model using

appropriate empirical methodologies and sample sizes for relevant supply chains.

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